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Regeneration and its effect on virtual lengths on electric railways, (1)

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Figs. 1 to 7, pp. 455 to 469.

The alternating current motor with rotating field and the continuous current shunt excited motor are known to have the property of acting as current generators when, the direction of rotation of the rotors remaining unchanged, the speed exceeds a certain value.

Under such circumstances, they feed current to the line to which they are connected, and this causes the phenomenon briefly described by the wording « *regeneration of electric energy* ». This description originated as a result of a particular application of these motors in which this particular feature is of especial importance : that is to say, their application to traction purposes on railways. The amount of energy expended in propelling a train on a section having a certain rising gradient is greater than that needed to move the train along the level : the difference is recovered either in total or in part when a similar train runs over the same section in the opposite direction.

The continuous current shunt wound motor is only used for traction purposes to a small extent, being limited to accumulator locomotives. The asynchronous alternating current motor on the contrary is principally used for main line railway traction, so that the phenomenon in question deserves particular investigation as regards this latter motor.

The problem of the choice of the most suitable system of current for electric traction has been considered in many papers (2). The longitudinal section of lines to be electrified is an important factor in the problem and is frequently brought forward as favouring three phase current, on account of the regeneration possible with this system.

Let us therefore see what is, in concrete terms, the importance of regeneration, and in what way are its characteristics shewn.

The research we propose to make is of value from another point of view. The

(1) Translated from the French.

(2) Corini : *Problemi ferroviarie italiani*, Publishers, Donati, Parme, and *Bulletin of the Railway Congress*, number for January 1928, p. 93.

calculation of the virtual lengths of the lines operated by steam traction, from the point of view of mechanical work done, can generally be made by using the formula :

$$l_v = l_r \left(1 \pm \frac{i}{r}\right) \ldots\ldots \quad (1)$$

in which

l_v = the virtual length,
l_r = the actual length,
i = the gradient in millimetres per metre.
r = the tractive resistance on straight level track expressed in kilogrammes per metric ton of train weight.

The formula (1) can be applied in each case in which it is correct for $i > 0$ when we have $|i| < |r|$ $i < 0$.

The Italian State Railways use this expression in the following form :

$$L_v = L_r + \frac{h + \Sigma l_r p}{5} \ldots\ldots \quad (2)$$

wherein h represents the difference in level between the extreme ends of the line and p the gradients which are adopted as being equivalent to the curves. The formula (2) applies to any value of i when h is positive : it is correct for $|i| \leqslant 4$ when h is negative.

When $|i| \geqslant 5$ and h is negative, we can always take (1)

$$L_v = \frac{1}{5} L_r \ldots\ldots \quad (3)$$

The formulæ (1), (2) and (3) can be applied approximately to lines operated by electric traction using locomotives which do not admit of regeneration. The only correction needed is to the constant of L_r in formula (3) which should be less than 1/5 seeing that, whilst losses due to braking must be taken into account, such losses as those due to boiler radiation can be ignored. In any event, it is evident that the formulæ given above cannot be applied in the case in which the line is operated with locomotives which regenerate current. We propose in consequence to determine the formulæ for calculating the virtual lengths to be applied in such a case.

The mechanical characteristic of the asynchronous motor with rotating field, as one knows, is defined by the equation :

$$C = \pi N B^2 S^2 \frac{r}{r^2 + 4\pi^2 L^2 (n - m)^2} (n - m) \quad (4)$$

in which

C = the motor torque,
N = number of turns of wire in the rotor,
B = rotor inductance,
S = section of wire,
r = resistance of the motor,
n = revolutions per second of rotating field, equal to the current frequency divided by the number of pairs of poles of the stator,
m = revolutions per second of rotor,
L = constant of self-induction of the windings of the rotor.

The variables C and m in formula (4) give a curve of the form of figure 1.

The part ABC of the curve, with positive ordinates, corresponds to values of $m < n$ the case when the machine in acting as a motor.

The branch CDE, with negative ordinates, symmetrical in form with that above, corresponds to the machine acting as a generator.

The curve gives a maximum and minimum (negative maximum) corresponding to the values of m_1 and m_2 obtained by solving the equation :

$$r^2 = 4\pi^2 (n - m)^2 L^2 \ldots\ldots \quad (5)$$

When r varies, the values of m_1 and m_2 also vary, whilst the maximum and minimum points B and D move along the horizontal lines GB and DH parallel to O_m. For $r = 2\pi n L$ . . (5) the maximum of C is found when $m_1 = 0$ and the minimum when $m_2 = 2n$. The curve when developed follows the line GCH.

(1) Corini : *Lezioni di ferrovie.*

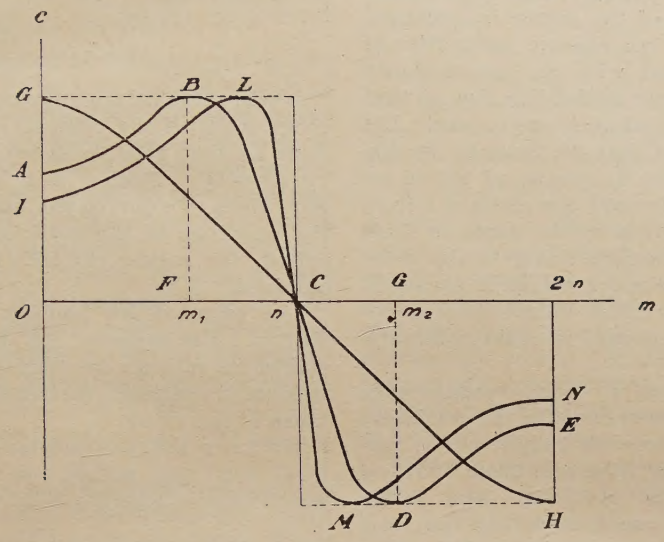
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Fig. 1.

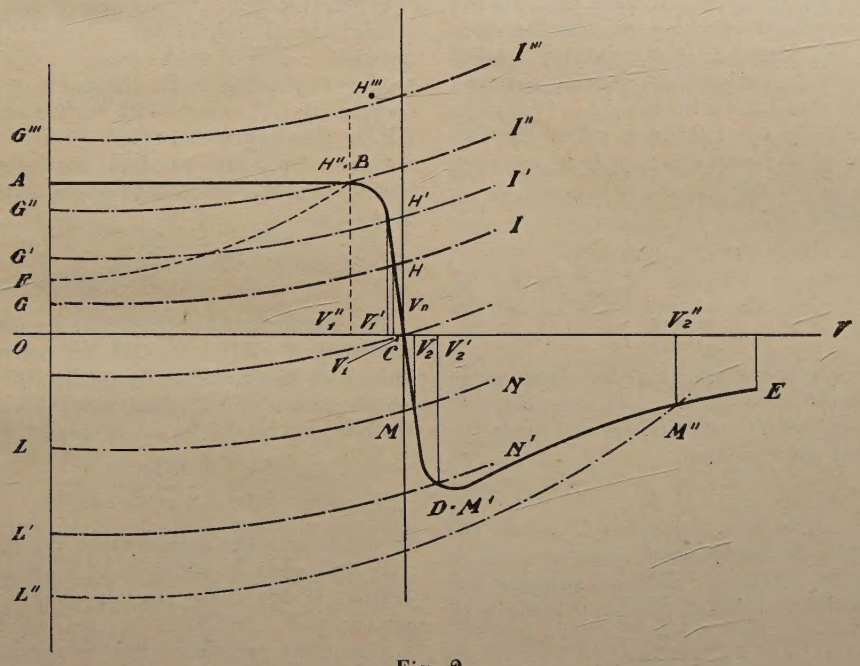
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Fig. 2.

After again noting these well-known characteristics of the motor in question, let us consider an electric locomotive of weight P, fitted with an asynchronous three-phase motor of definite size, so that the terms of equation (4) are known. Let us also suppose that we have at our disposal a rheostat by means of which we can continuously vary the value of r from the maximum given by the equation (5) to the minimum corresponding to the short circuiting of the rotor windings arranged in star or in delta form. The curve ILCMN corresponds to this minimum value of r.

When starting, r varies continuously from the maximum down to the minimum indicated. A series of characteristic curves, very close together, from GCH to ILCMN will be obtained. The motor torque will be constant during the start and equal to the maximum BF. The motor having started, the arm LC of the curve will be used, as with it the highest outputs are realised. We can indicate the tractive effort at the tread of the tyre by T, the diameter of the driving wheels by D and the ratio of the gearing between the motor and the wheels by δ. We know that usually $\delta = 1$ is used when the frequency of the current supply is between 16 and 17 periods.

We then get :

$$\left.\begin{aligned} C &= \frac{D}{2\delta} T \\ V &= \frac{\pi D}{\delta} m \end{aligned}\right\} \quad \ldots\ldots \quad (6)$$

wherein V = the speed of the locomotive in metres per second. Let us substitute these values in equation (4) and draw the curve of the equation :

$$T = T(v).$$

The curve has the same form as the curve $C = C(m)$ obtained from formula (4) shewn in figure 1. Let us suppose the locomotive is hauling a train of weight Q

Let

$$\tau = \frac{T}{P + Q} \quad \ldots\ldots \quad (7)$$

the tractive effort per metric ton of train : let us draw the curve

$$\tau = \tau(v).$$

It will coincide with the curve $T = T(v)$ if we read off the ordinates to the same scale as that used to draw $T(v)$ divided by $(P + Q)$. Taking into consideration the values of τ during the start and when the windings of the rotor are short circuited, the curve ABCDE (fig. 2) will be obtained.

The segment BC belongs to the curve FBC ... ; the segment AB is where the maximum values τ are obtained during the start with continual variation in the resistance of the rotor.

We know that the resistance on straight level road per metric ton of the train weight can be expressed by an equation

$$R = a + bV^2 \quad \ldots\ldots \quad (8)$$

which can be represented by the parabola GHI.

When the train travels over a section of straight level line, the dynamic equilibrium between τ and R takes place at the speed V_1 corresponding to H, the point of intersection of the curve GHI with the curve BHC. The segment BC being only a small distance from the vertical, V_1 differs but little from V_n, the speed of synchronism given by

$$V_n = \frac{\pi D}{\delta} n.$$

The segments of ordinates lying between the curves ABH and GH represent the values of the acceleration when starting as a function of V. They should be made to the scale of the forces divided by

$$\frac{1\,000\,\alpha}{g}$$

in which g is the acceleration due to gravity and α the co-efficient of inertia of the train. If the train travels over a rising gradient of i millimetres per metre (we suppose the resistance due to curves to be included in i) the tractive resistance per

metric ton of the train weight is given by

$$R' = i + a + bV^2.$$

This resistance is represented by the curve G'H'I' having its ordinates equal to those of the curve GHI increased by the segment GG' representing, to the scale of the forces, i kgr. The dynamic equilibrium is reached at the speed V'_1 corresponding to the point H' of intersection of the curve BC with the curve G'H'I'. $V'_1 < V_1$, but the difference between V'_1 and V_1 and consequently also between V'_1 and V_n is small. The steepest gradient the locomotive can negotiate when hauling the weight Q is given by the value J_1 represented by the segment GG'', G''H''I'' being the parabola of the type $R_x = i_x + a + bV^2$ passing through B.

If the slope had the value represented by the segment GG''', the locomotive would come to a stop and the slowing down would be represented by the segments included between the curves H'''G''' and BF.

Let us designate by $\tau_{max.}$ the maximum value of τ represented by BV''_1. We get :

$$\tau_{max.} = J_1 + r\,(v'')$$

and consequently

$$J_1 = \tau_{max.} - r\,(v''). \quad . \quad . \quad . \quad . \quad (9)$$

having taken

$$R = a + bV''^2 = r\,(v'').$$

When the train runs on to a down gradient, that is to say, with i negative, the resistance is given by :

$$R = -i + a + bV^2$$

And the curve representing R is obtained by reducing the ordinates of GI by the segment representing i.

If we have :

$$i < 0 \text{ et } |i| = |a + bV^2|,$$

$R = 0$ and the parabola representing the resistance passes through V_n. The current used by the locomotive is nil.

When the train comes on to a section having a down gradient

$$|i| > |a + bV^2_n|,$$

the parabola representing the resistance follows the line LMN and meets the negative branch of the characteristic curve at the point M. A tractive effort τ is then applied to the engine per unit of weight of the train represented by MV_2. Consequently the locomotive generates current and produces the energy measured by :

$$\psi \cdot 10_{-3}\tau\,(P + Q) \cdot V \cdot g \text{ kilowatts,}$$

ψ being the co-efficient of output of the motor working as a generator. The speed V_2 of the locomotive is little more than V_n and consequently only slightly exceeds the allowed speeds when the machine works as a motor. If the down gradient become steeper, the tractive effort acting on the locomotive increases and, as a result, the energy it produces.

When the down gradient reaches the value

$$|J_2| = |a + b\,V'^2_2 + \tau_{max.}|,$$

the parabola representing the resistances L'M'N' passes through the point corresponding to the minimum of the characteristic curve. The speed of the locomotive becomes V'_2 which differs but little from V_n and the speeds previously considered.

If the down gradient reached a value such as

$$|i| > |J_2|$$

the curve of the resistances would develop on the lines of L''M'' and would cut the characteristic curve at the point M''.

This point corresponds both with a certain amount of energy generated by the engine, which is less than that at the point M', and to a speed distinctly higher. Above the value J_2 the speeds increase quickly and are incompatible with regular and steady running conditions. For down gradients of an absolute value less than J_2, the running of the train is automatically regulated by the locomotive which, acting as a generator, acts as an electromagnetic brake, keeping the speed within a little of V_n : but for down gradients of an absolute value steeper than J_2, the brake proper must be used to keep the speed close to that of V'_2.

Whilst the machine is generating the

same quantity of energy as it produces in the down gradient J_2, a known quantity of energy must be expended by the brakes. In fact the energy regenerated is given by the difference between these two values.

Everything said above still stands if the value V_n was small and if we took speeds sufficiently higher than V_n for the energy regenerated at a speed much higher than V'_2 to be less than that corresponding to V'_2.

Conclusion : *An electric locomotive fitted with an asynchronous three-phase motor having a synchronising speed* V_n *and able to develop a maximum tractive effort* $\tau_{max.}$ *at the tread of the wheel for each metric ton of the train weight can ascend the gradient*

$$J_1 = + \tau_{max.} - (a + bV^2_n). \quad . \quad (11)$$

The same locomotive can work over a down gradient and regulates its own speed until the gradient becomes a maximum (maximum in absolute value)

$$J_2 = \tau_{max.} + (a + bV^2_n). \quad . \quad . \quad (12)$$

The electric energy generated by the locomotive varies from zero when

$$|i| = |a + bV^2_n|$$

up to the value in kilowatts :

$$W = \psi \cdot 10^{-3} (P + Q) \tau_{max.} V_n \cdot g \quad (13)$$

for $i = J_2$.

On sections on falling gradients

$$|i| > |J_2|$$

the mechanical brakes have to be used to keep the speed at about the value of V_n *whilst producing the same quantity of energy as that given by equation (13), and whilst expending the energy required for the brakes.*

Now let us consider a section AB of down gradient i and of length l so that $i < J_1$ defined by formula (11). If, at the beginning of the section, the train is running at the correct speed V_n, the work done to run over the section AB with the train weighing $P + Q$ is given by

$$L_1 = \tau (P + Q) \cdot l = (r + i) (P + Q) \cdot l.$$

When the losses in the electric conductors and in the motor are taken into account, the energy supplied by the sub-stations is given by

$$L'_1 = \frac{1}{\eta_1} (r + i) (P + Q) l. \quad . \quad . \quad (14)$$

in which η_1 is the product of the efficiency θ of the distribution of electricity along the trolley line by the efficiency φ of the motor : $\eta_1 = \theta \cdot \varphi$. Now let us suppose that the same train with the same locomotive, or with the same locomotives, runs over the section in the opposite direction.

It is obvious that if $i < J_1$, for greater reason we shall have :

$$i < J_2,$$

given by equation (12). The section AB will be run over without using the power brakes. The work required for the journey BA is given by

$$L'_2 = (r - i) (P + Q) l \quad . \quad . \quad (15)$$

If $i > r$, the quantity of energy regenerated in the sub-station will be

$$L'_2 = \eta' (i - r) (P + Q) l. \quad . \quad . \quad (16)$$

in which $\eta' = \theta \cdot \varphi$.

In order to put a value on the extent of this regeneration, the value of L'_2 given by equation (16) must be considered in conjunction with the work done during the outwards journey. The work done on the outwards journey is given by the equation (14); we then get :

$$\varepsilon = \frac{L'_2}{L'_1} = \frac{\eta' (i - r) (P + Q) l}{\frac{1}{\eta_1} (i + r) (P + Q) l} \quad . \quad (17)$$

whence

$$\varepsilon = \eta_1 \eta' \frac{i - r}{i + r} \quad . \quad . \quad . \quad . \quad . \quad (18)$$

The equation (18) has a meaning when $i \geqslant r$. When $i < r$, ε is negative, that is to say, instead of regeneration, a certain quantity of energy is consumed. The values of ε vary between the following limits :

$$\left.\begin{array}{l} \text{for } i = r \quad \varepsilon = 0 \\ \text{for } i = J_1 \quad \varepsilon = \eta_1 \eta' \dfrac{\tau_{max.} - (a + bV^2_n)}{\tau_{max.}} \end{array}\right\} (19)$$

If P be the weight of the locomotive, we obviously have

$$\tau_{max.} \leqslant \frac{1\,000 f P}{P+Q},$$

in which f is the coefficient of adhesion. In heavy railway traction on lines with steep gradients, double heading is used, or trains made up so that the ratio $\frac{P}{P+Q}$ varies from 1/4 to 1/6, whilst for V_n values of the order of 75 km. an hour are selected. In this case, if we suppose

$$\frac{P}{P+Q} = \frac{1}{5}:$$

(Example : P = 50 t. ; Q = 200 t).

$$\tau_{max.} = \frac{1}{5} \times 1\,000 f$$

For $f = \frac{1}{7}$, we have :

$$\tau_{max.} = 29 \text{ kgr. per metric ton.}$$

If we made $a = 2.5$, $b = \frac{1}{1\,500}$, we get :

$$a + b V^2 = 6.25 \text{ kgr.}$$

And finally, if we suppose $\eta_1 = 0.90$ and $\eta_1' = 0.80$,

$$\varepsilon = 0.41.$$

Let us now suppose that the weight hauled being the same in the direction AB as in BA, double heading is used when ascending the gradient and a single engine when going down it.

On the rising gradient we have :

$$\tau_{max} = 2 \times \frac{1\,000 f P}{2P+Q} \quad \ldots \quad (20)$$

and down it :

$$\tau_{max.} = \frac{1\,000 f P}{P+Q} \quad \ldots \ldots \quad (21)$$

Then, if we suppose we have $i < J_1$ it may happen that $i > J_2$.

In this event, we determine the energy recuperated by means of the equation (16) replacing i by J_2 and by cutting out the work done in braking which can be calculated approximately from the expression $\nu (i - J_2)(P + Q) l$, wherein ν is a constant less than unity. We shall then have :

$$L''_2 = \eta' (J_2 - r)(P + Q) l - \nu (i - J_2)(P + Q) l \quad \ldots \quad (22)$$

The expression (18) then becomes :

$$\varepsilon = \frac{L''_2}{L'_1} = \eta_1 \frac{\eta' J_2 - r) - \nu (i - J_2)}{i + r}. \quad (23)$$

For reasons we shall give later, we take for $\nu (i - J_2)$ the value 1 ; we then get :

$$L''_2 = (P + Q) l [\eta' (J_2 - r) - 1]. \quad (22')$$

$$\varepsilon = \eta_1 \frac{\eta' (J_2 - r_/ - 1}{r + i} \quad \ldots \quad (23')$$

With the quantities allowed previously, we get for the formulæ (21) and (22) :

$$\tau_{max.} = \frac{1}{5} 1\,000 f = 29 \text{ kgr per metric ton.}$$

$$J_2 = 35.25.$$

For the formulæ (20) and (11) :

$\tau'_{max.} = 47$ kgr. per metric ton. $J_1 = 40.75$.

for $i = J_2$. $\varepsilon = 0.477$.

for $i = J_1$. $\varepsilon = 0.432$.

The difference is small.

If we give the ratio $\frac{P}{P+Q}$ values which do not correspond with those of trains on the main railway lines proper but with those running usually on tramways, we can make $\frac{P}{P+Q} = \frac{1}{2}$, with V = 25 km. an hour and we get :

$\tau_{max.} = 70$ kgr. per metric ton, $a + bV^2 = 3$ kgr. per metric ton and $J_1 = 63$ millimetres per metre

The expressions (19) become :

for $i = r$. $\varepsilon = 0$.

for $i = J_1$ $\varepsilon = 0\ 648$.

Let us now suppose that on rising gradients two engines are used, and on down gradients one engine is used. We get :

$J_1 = 91\ ^{00}/_{00}$. $J_2 = 73\ ^{00}/_{00}$,

and the equation (23) gives the following results :

$$\text{for } i = J_2, \qquad \varepsilon = 0.675,$$
$$\text{for } i = J_1, \qquad \varepsilon = 0.513.$$

In this case the co-efficient of regeneration falls rapidly as the down gradient increases above J_2.

To calculate the economical effects of regeneration, it is not enough to determine the percentage proportion of the energy used on rising gradients which is regenerated when running down them, but it is necessary to calculate the saving of energy realised with the regenerating locomotive during the two trips, one up and the other down the gradient, in relation to the energy used by a non-regenerating locomotive.

In this way we find the down gradient i such that $r < i < J_2$.

a) Train with non-regenerating locomotive :

$$\text{Trip AB : } L'_1 = \frac{1}{\eta_1}(r+i)(P+Q)\,l.$$

$$\text{Trip BA : } L''_1 = \frac{1}{\eta_1}(P+Q)\,l \quad \nu(i-r).$$

in which L''_1 represents the work in braking to keep the train at a steady speed ; ν is a constant smaller than unity.

We then have : $$L_1 = L'_1 + L''_1 = \frac{1}{\eta_1}(P+Q)\,l\,[r+i+\nu(i-r)] \quad \ldots\ldots\ldots \quad (24)$$

b) Train with regenerating locomotive :

$$\left.\begin{aligned} &\text{Trip AB : } L'_2 = \frac{1}{\eta_1}(r+i)(P+Q)\,l \\ &\text{Trip BA : } L''_2 = -\eta'(i-r)(P+Q)\,l \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots \quad (25)$$

in which L''_2 represents the energy regenerated.

We have therefore :

$$L_2 = L'_2 + L''_2 = (P+Q)\,l\left[\frac{1}{\eta_1}(r+i) - \eta'(i-r)\right] \quad \ldots\ldots\ldots \quad (26)$$

The energy saved by the regenerating locomotive is given by :

$$L_1 - L_2 = (P+Q)\,l\left[\frac{1}{\eta_1}\nu(i-r) + \eta'(i-r)\right]$$

and unit economy by :

$$\sigma = \frac{L_1 - L_2}{L_1} = \frac{\nu(i-r) + \eta_1\eta'(i-r)}{\nu(i-r) + r + i}.$$

As we have noted, the formula for virtual lengths for steam locomotives used by the Italian State Railways for negative gradients and of the absolute value $|i| \geqslant |r|$ can be brought into line with the formula (3) in which we have considered $r = 5$, which is equivalent to supposing the energy consumed in braking less or at most equal to $(P+Q)\,l$ (1).

---

(1) The work on down gradient i

$$L''_1 = (P+Q)(r-i)\cdot l + F$$

F being the work done in braking.

If l_v is the vertical length, as defined :

$$L''_1 = (P+Q)\cdot r\cdot l_v$$

Thence :

A) $$(P+Q)(r-i)\cdot l + F = (P+Q)\cdot r\cdot l_v.$$

For $|i| \geqslant r$, the first term is nil, the equation (3), adopted by the Italian State Railways is :

B) $$l_v = \frac{l}{r}$$

in which we have taken $r = 5$.

The equation (A) thus becomes :

$$F = (P+Q)\cdot r\cdot \frac{l}{r} = (P+Q)\cdot l.$$

In other terms, from the formula we ought to have :

$$\nu\,(i - r) \leqslant 1.$$

If as a rough approximation we take the value 1, we get :

$$\sigma = \frac{1 + \eta\eta'\,(i - r)}{1 + r + i} \quad \ldots \quad (27)$$

The value of σ given by equation (27) takes no account of the energy expended at starting or stopping the train The research work necessary to take these factors into account is not difficult theoretically : it leads however to a formula of little practical value as it never happens that the normal starts and stops take place on sections with severe down gradients. With a view to calculating the value of regeneration in its economical effects, all that is needed is to introduce in the second term of the equation (18) a constant less than 1 and varying according to the conditions of the lines : if it is desired to arrive closely at the energy regenerated in each particular case, it will be better to resort to the graphical methods that will be described later. In limiting ourselves to the first of these two objects, we will write equation (27) in the following form :

$$\sigma = \xi \frac{1 + \eta\eta'\,(i - r)}{1 + r + i} \quad \ldots \quad (27')$$

Even for the lines classed as mountain lines, we can take the *mean value* of i as not much exceeding 10 millimetres per metre.

Taking the value $i = 12$, we get :

V in kilometres per hour.	$r = 2.5 + \frac{1}{15}\left(\frac{V}{10}\right)^2$	$\xi = 0.95$ $\eta = 0.9$; $\eta' = 0.8$ σ	$\xi = 0.95$ $\eta = 0\,8$; $\eta' = 0\,75$ σ
25	3	0.43	0 38
50	4.15	0.36	0.33
75	6.2	0.26	0.22
100	9.1	0.13	0.11

As these quantities shew, the coefficient of regeneration is high for low speeds and rather low for high. On the Giovi lines, in Italy, with maximum gradients of 35 ‰ and 17 ‰, a saving of about 14 % of the annual current consumption was obtained.

The cost of traction per metric ton-kilometre excluding the cost of staff can be represented by a formula of the following type (1) :

$$S = 10^{-3}\,We + \frac{Cr'}{\zeta} \quad \ldots \quad (28)$$

in which

W = number of watt hours per metric ton-kilometre,

e = price of electric energy per kilowatt-hour,

C = cost of the electrification per kilometre of track,

r' = annual cost including amortization and a proportion of the upkeep of the installations,

ζ = annual number of metric ton-kilometres per kilometre of track electrified.

(1) Corini : « Tipi e sistemi di trazione » (*Rivista dei Trasporti*, 1922.).

If W is the value which applies to lines with electric traction without regeneration, it is necessary in formula (28) for lines with electric traction with regeneration to substitute for the value W the value $W \cdot \sigma$. It will be found from equation (28) that in the example considered, *when the costs of the installations are the same, regeneration of energy gives a saving of traction cost (excluding staff) which varies from 15 to 3 5 %, and is on an average 9 %. In the case of equal traction costs, a regenerating system can be adopted in preference to one without regeneration (other factors being ignored) even when the costs of the installation exceed those of the latter system in a proportion of between 15 and 3.5 % or, as a mean, 9 %. In the case of falling gradients of less than 8 millimetres per metre (1 in 125), the saving due to regeneration becomes very small.*

If it be realised that the cost of hauling trains (excluding that of the staff concerned) represents a small percentage of the general operating costs (something like 10 %), it will be appreciated that the economic value of regeneration as regards the operating balance sheet amounts to about 1 % of the total operating expenditure in the case of lines having down gradients averaging 12 millimetres per metre (1 in 83) : and that, on the other hand, it is inappreciable on lines having down gradients of less than 8 millimetres per metre (1 in 125) (1).

The figures 3 to 7 reproduce the graphical solution in any concrete case to determine the values of ε and σ. Let us suppose it is a question of a train in which $\frac{P}{P+Q} = \frac{1}{6}$. This would be the case of a train of 450 metric tons double headed by two electric locomotives, each weighing 45 tons. The maximum tractive effort per metric ton of train would be 24 kgr.

If we suppose the locomotives to be fitted with three-phase asynchronous motors capable of developing together a tractive effort at the driving wheel treads of 24 kgr. per metric ton of weight and that the synchronising speed for a given number of poles corresponds to a train speed of 75 km. an hour In figure 3 the abscissa OC is the axis of the train speeds to the scale of 1 millimetre = 1 km. an hour ; the ordinate Oτ is the axis of the tractive efforts per metric ton of train to the scale of 1 kgr. = 1 millimetre (1).

The straight line AB represents the position of the maximum tractive efforts obtained when starting with the continual variations of the resistance of the rotor windings from the value $r = 2\pi nL$ to the resistance value of the windings when short circuited. The curve BC is the falling part of the characteristic curve as a whole of the motors for the minimum value of the resistance and for the values of the speed varying from 67 to 75 km. an hour (supposing a range of 10 %). The curve CDE is the characteristic curve as a whole of the motors acting as generators. The curve *ab* is the resistance to movement on straight level line per metric ton weight of train as a function of the speed represented by the equation :

$$R = 2.5 + \frac{1}{15}\left(\frac{V}{10}\right)^2.$$

The segments of the ordinates included between the curves AB*b* and *ab* have been used to construct the curve W (*v*) of

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(1) Corini : « Tipi e sistemi di trazione » (*Rivista dei Trasporti*, 1922.)

One important consequence of braking by regenerating is that the energy made available is not only recovered, but that it is not used destructively in wearing away the rails and brake shoes.

In addition, when braking by regeneration the varying action of the brake shoes, which depends upon the speed and atmospheric conditions, is replaced by a constant force.

These favourable conditions have, as regards the operating department, a greater value than the regeneration of the energy itself.

(1) The figures have been reduced in the ratio of 3 to 2.

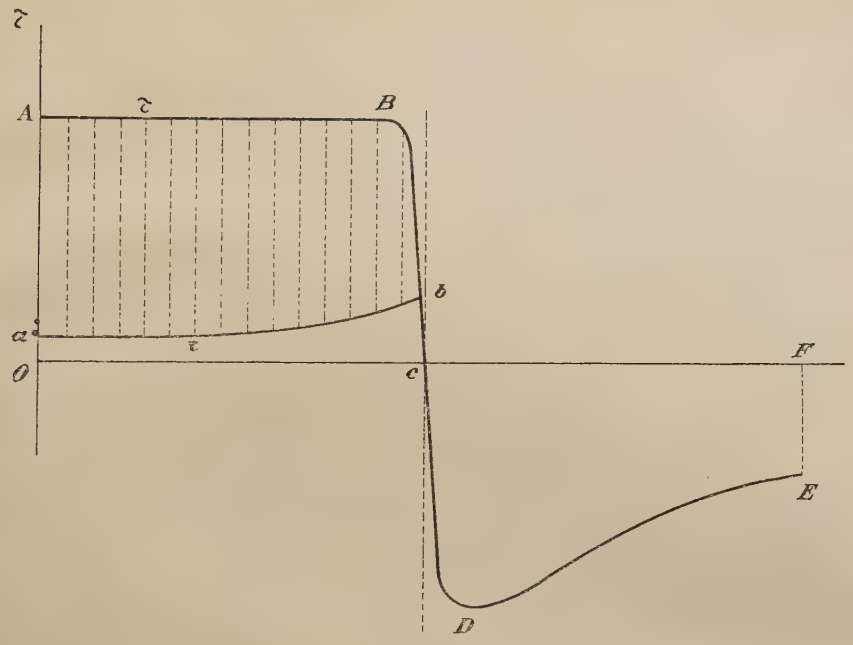


Fig. 3.

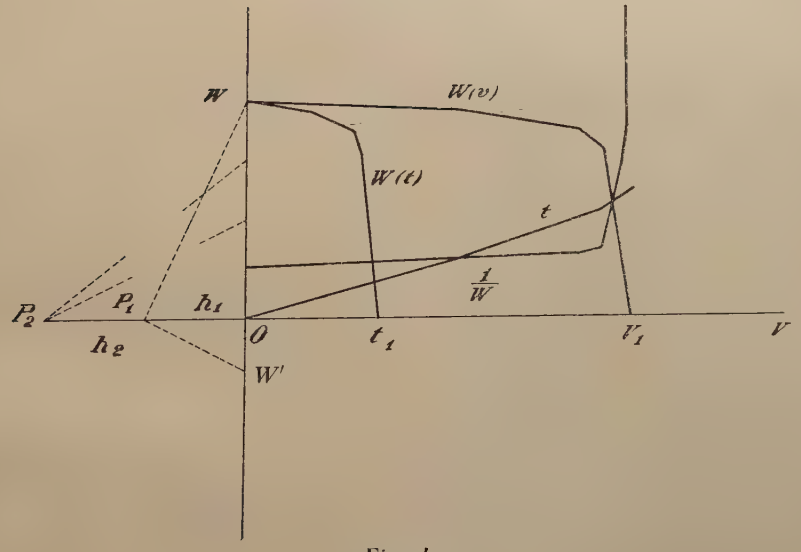


Fig. 4.

Polar distances :

$h_1 = 20$ millimetres.
$h_2 = 40$ —
$h_3 = 91$ —

Scales :

Forces	1 kgr. =	2 millimetres.
Speeds	1 km. per hour =	1 —
Acceleration	1 cm. per sec^2 =	2 —
— reciprocals	1 sec^2 per cm. =	200 —
Time	1 sec. =	5/27

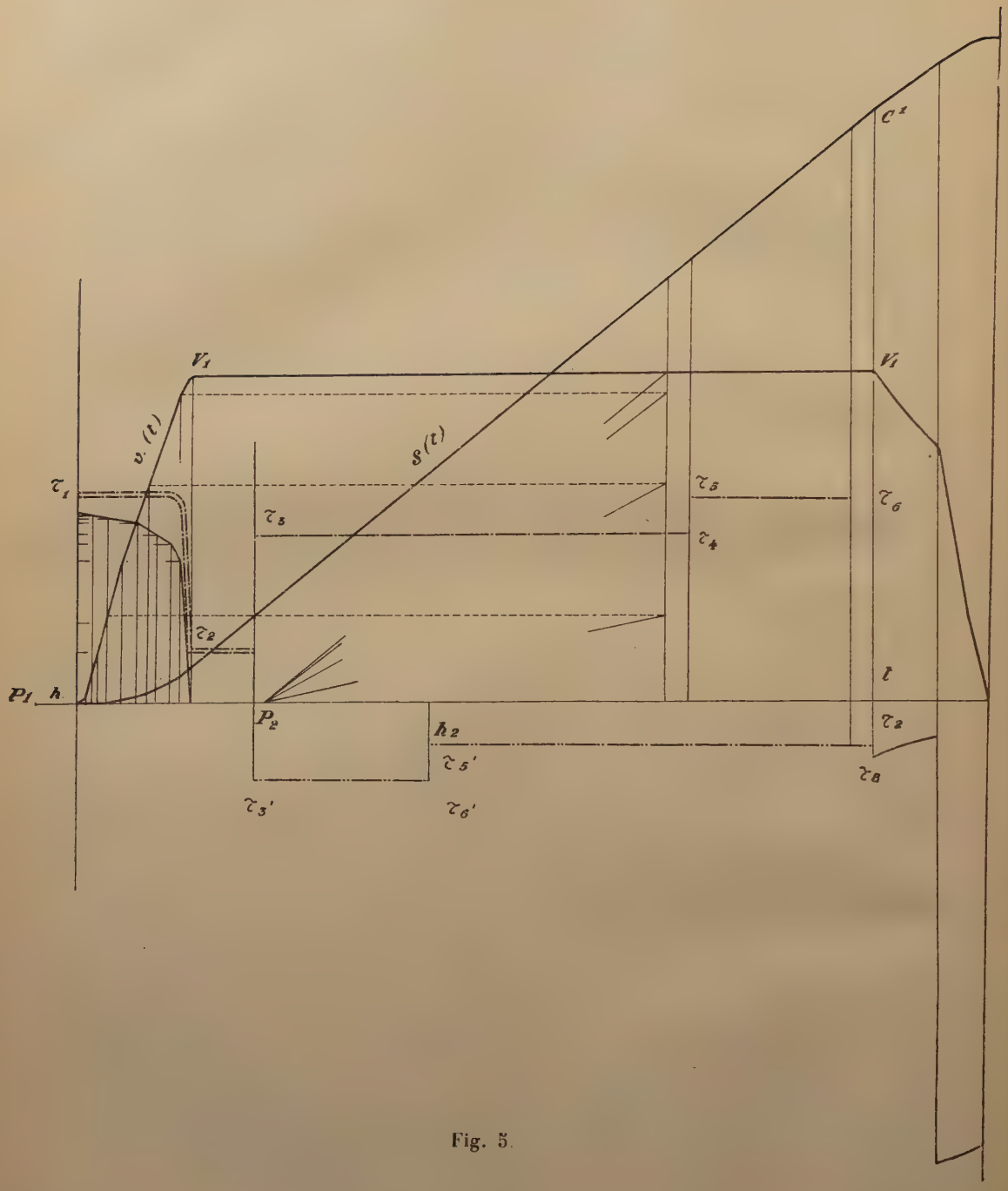

C^1
V_1
V_1
$v.(t)$
$s^{(t)}$
τ_1
τ_5
τ_6
τ_3
τ_4
τ_2
p_1
h
t
p_2
h_2
τ_2
τ_5'
τ_8
τ_3'
τ_6'

Fig. 5.

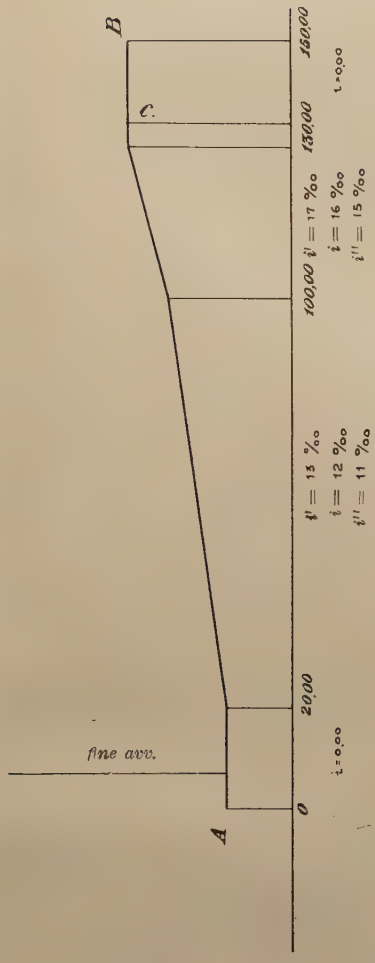


Fig. 5 (*continued*). — Scale of figure 5.

Length. . . . . 1 centimetre = 1 km. | Height. . . . . 1 millimetre = 10 m.

figure 4 in the diagram having for its abscissæ the speeds to a scale of the previous figure and for ordinates the accelerations in the starting period, to the scale of 1 cm. per second per second = 2 millimetres.

By projecting the ordinates of the curve W (v) on to the axis oW and by drawing right angle triangles such as WP_1W' of height $h = 10$ millimetres, we get the curve $\frac{1}{W(v)}$, the ordinates of which, representing seconds per seconds per centimetre are drawn to the scale of 1 second per second per centimetre = 200 millimetres.

With the polar distance $h_2 = 40$ millimetres, the curve $\frac{1}{W(v)}$ has been integrated, and the curve t (v) has been obtained, the ordinates of which are drawn to the scale of 1 second $= \frac{5}{27}$ millimetres.

Finally, taking as abscissæ the ordinates of the curve t (v), and as ordinates the corresponding ordinates of the curve W (v), we have drawn the curve W (t) which gives the acceleration when starting as a function of the time to the scale previously mentioned. The time taken in starting was 135 seconds. The acceleration period varies from 22 cm. per second per second to zero. All this applies to a line on the level.

In figure 5 we have drawn the profile of the section of line with which the present investigation deals. Two level stretches 2 km. long have been taken at the ends with an intermediate section 8 km. long, with a gradient $i = 12$ millimetres per metre (1 in 83), an imaginary rising gradient of 13 millimetres per metre (1 in 77) (taking the curves into account) an imaginary down gradient of 11 millimetres per metre (1 in 90), and a second section 3 km. long having $i = 16$, $i' = 17$, $i'' = 15$.

For this, in figure 5, the abscissa being taken as the time axis, we have transposed the curve W (t) of the acceleration : with à polar distance $h_1 = 10$ millimetres,

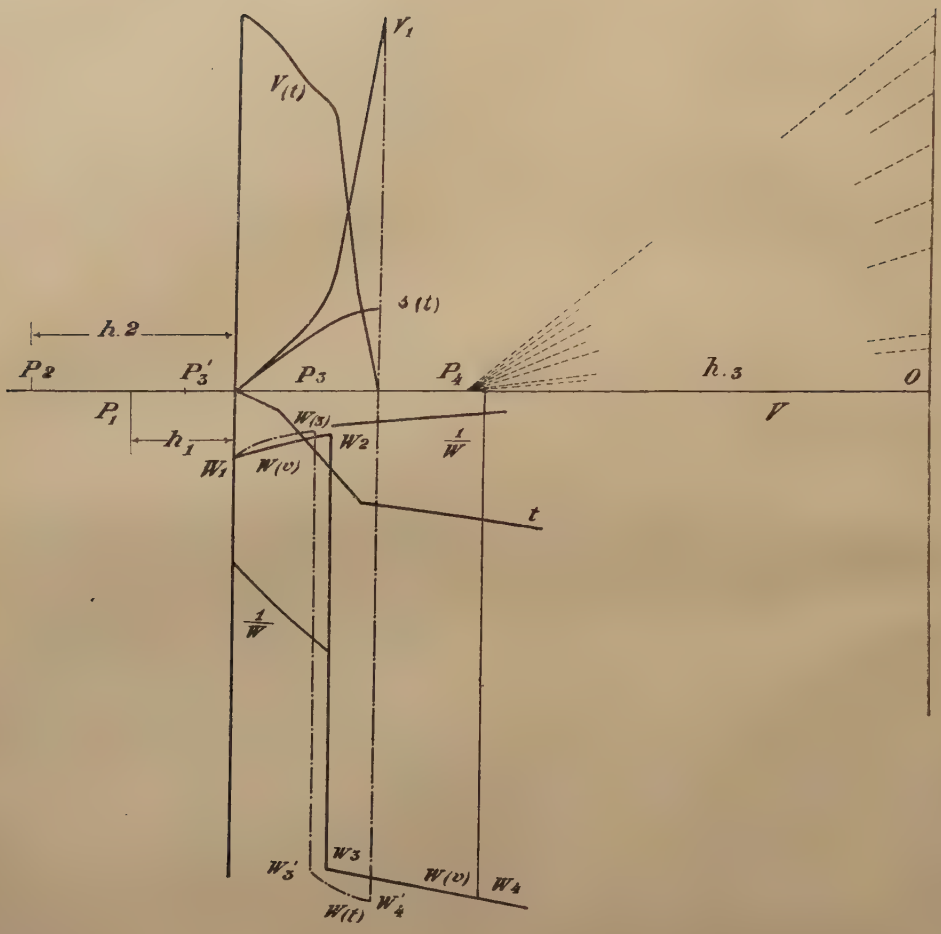


Fig. 6.

Polar distances :

$h_1 = 20$ millimetres.
$h_2 = 40$ —
$h_3 = 91$ —

Scales :

Forces	1 kgr. =	2 millimetres.
Speeds	1 km. per hour =	1 —
Acceleration	1 cm. per sec^2 =	2 —
— reciprocals	1 sec^2 per cm. =	200 —
Time	1 sec. =	5/27 —

chosen so that the scale of speeds should be the same as that already fixed, the curve W (t) has been integrated and the curve of the speed v (t) during the starting period obtained.

The straight line V_1 V_1 parallel to the abscissæ represents the speed during the whole journey up to the *coasting period* or running with current off. We have neglected the variations of speed due to

variations of τ and that because, as has been said, the differences in the speed do not exceed 10 %. With the polar distance $h = 91$ millimetres chosen so that the ordinates of the curve of distances shall be to the same scale as to that of the line profile, the curve $v\,(t)$ has been integrated and the curve $s\,(t)$ obtained.

To determine the point C of the line at which the *coasting* period should begin, we proceed as follows (see fig. 6).

Let us take the speed as being reduced by 25 % before braking starts. We draw the curve W_1W_2 representing the values

$$\frac{1000\,\alpha}{g}\,W = -\,R = -\left[2{,}5 + \frac{1}{15}\left(\frac{V}{10}\right)^2\right]$$

between the values :

V = 75 km. an hour and V = 56 km. an hour.

This curve to the scale of 1 cm. per second = 2 millimetres represents the reduction of speed during the *coasting* period. At the speed V = 56, braking commences, and we suppose that the resistance has a value of 45 kgr. per metric ton of train. We also suppose that the resistance increases according to the ordinates of the straight line W_3W_4, the coefficient of friction between the shoe and the tyre following the law :

$$m = \alpha - \beta V^2$$

β being a constant much greater than the constant of V^2 in the expression for R.

With the polar distances used during starting, we have drawn the curve $\frac{1}{W(v)}$, $t\,(v)$, $w\,(t)$ and the curve $v\,(t)$ by integrating $w\,(t)$ from the left side of the diagram. The value V = 75 reached at point V_1 of the curve $v\,(t)$, we have brought the ordinate through V_1, $V_1\,W'_4$, which in this way reduces the portion of the diagram of the negative W's used when braking.

If we now integrate with the same polar distance the diagram of W (t) so defined, commencing from the right, we get the curve $v\,(t)$ for the *coasting* and braking periods. In integrating the diagram $v\,(t)$ with the polar distance $OP_4 = 91$ millimetres, we get the diagram $s\,(t)$ of distances during the *coasting* and braking periods.

After having transferred the last ordinate of this diagram on to the profile (fig. 5) starting from B to BC, we have in C the point from which the period of *coasting* ought to commence.

Projecting C in C' on the $s\,(t)$ of the working period, we get the point which fixes in t the moment in which the *coasting* periods begin. We have in this way the means of inserting in figure 5 the diagrams $w\,(t)$, $v\,(t)$, $s\,(t)$ for the *coasting* and braking periods, thereby completing these diagrams between the start and the arrival of the train. In the journey BA, the diagrams are identical with the preceding ones, the outer sections being supposed to be on the level.

The curves $\tau_1\,\tau_2\,\tau_3\,\tau_4\,\tau_5\,\tau_6\,\tau_7$ and $\tau'_1\,\tau'_2\,\tau'_3\,\tau'_4\,\tau'_5\,\tau'_6\,\tau'_7$ represent the diagrams of the tractive efforts in the journey AB and the journey BA

After having calculated the products of the ordinates of the curve $v\,(t)$ and $r\,(t)$ in taking as basis of reduction $b = 48$ millimetres, we have obtained in figure 7 curves representing the diagrams of the energy needed in travelling over the line AB with a regenerating locomotive as with one not regenerating; travelling from B to A with a locomotive not regenerating (as regards braking the previous hypotheses are adopted); in travelling over the line BA with a locomotive regenerating.

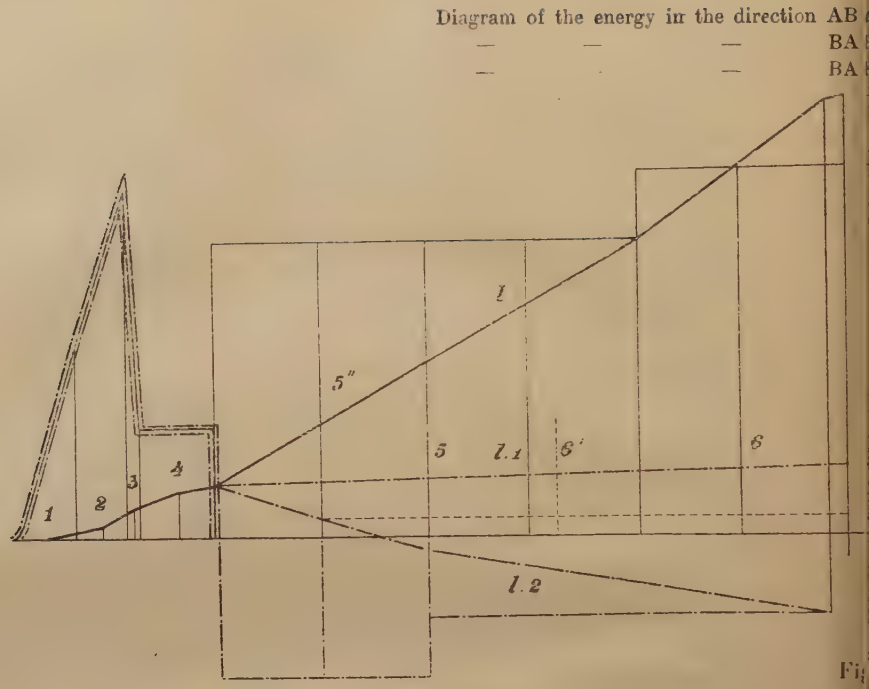
These diagrams are read to the scale :

1 watt $= \frac{1}{65}$ millimetre.

In integrating these diagrams with the polar distance $OP_4 = 100$ millimetres, we have obtained the curves representing the work needed to travel over the previously cited line from the start to any given point and to the end. The integrating curves have ordinates to the scale 1 kw.-h. = 100 millimetres.

The results apply to one metric ton of train. To get the values of the forces

Diagram of the energy in the direction AB
— — — BA
— — BA



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Scale : 1 watt. . . . . = 1/65 millimet
1 kw.-h. . . . . = 100 —

exerted, the power and the work in relation to the train, all that is required is to multiply the results by the weight of the train, expressed in metric tons.

From the curves l_1 l_2 l ignoring the level sections, we get :

for $\begin{cases} \eta_1 = 0.90 & \varepsilon = 0.230 ; \\ \eta_1' = 0.80 & \sigma = 0.25 ; \end{cases}$ for $\begin{cases} \eta_1 = 0.8 & \varepsilon = 0.19 \\ \eta_1' = 0.75 & \sigma = 0.20 \end{cases}$

Taking the level sections and starting into account :

for $\begin{cases} \eta_1 = 0.90 & \varepsilon' = 0.12 ; \\ \eta_1' = 0.80 & \sigma' = 0.16 ; \end{cases}$ for $\begin{cases} \eta_1 = 0.80 & \varepsilon' = 0.11 \\ \eta_1' = 0.75 & \sigma' = 0.14 \end{cases}$

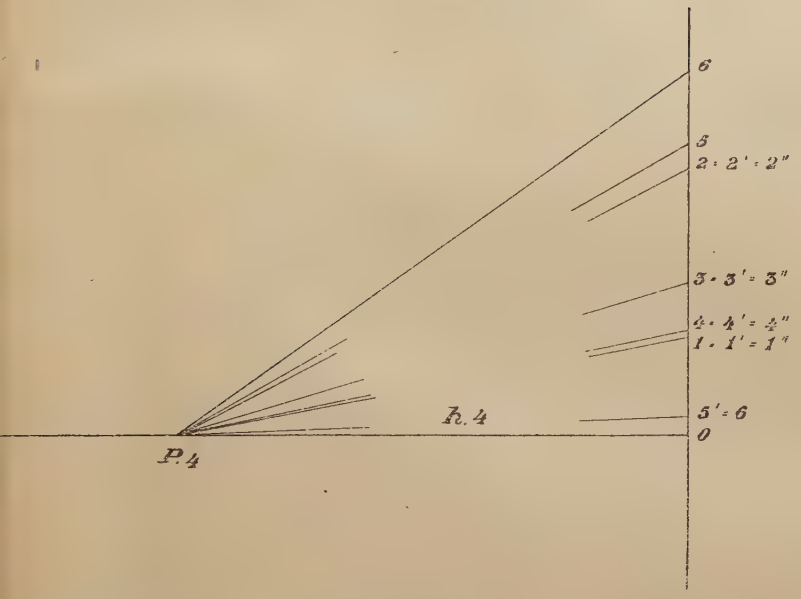
Supposing that, the starting period having just finished, the down gradient begins :

for $\begin{cases} \eta_1 = 0.90 & \varepsilon'' = 0.17 ; \\ \eta_1' = 0.80 & \sigma'' = 0.20 ; \end{cases}$ for $\begin{cases} \eta_1 = 0.80 & \varepsilon'' = 0.14 \\ \eta_1' = 0.75 & \sigma'' = 0.16 \end{cases}$

In the example considered, the journey between one stop and the next is short (15 km.) in respect to the length of the starting period, which is 800 m.

For through trains the distances without stop are considerably longer than those of the example considered. If, on the other hand, we consider starting periods in the direction BA on a section on down gradient, we shall be justified in introducing the co-efficient ζ which we have done for an investigation of a general character.

notive with and without regeneration.
egeneration.
neration.



Base of reduction. . . . $b = 48$ millimetres.
Polar distance. . . . . $h = 100$ —

If we take l_v the virtual length of the section of real length l and the gradient i in the direction AB in accordance with the definition itself of the virtual length, and when considering the first of the two equations (25), we have :

$$\frac{1}{\eta_i} r\,(P + Q)\,l_v = \frac{1}{\eta_i}\,(r + i\ (P + Q)\,l$$

whence

$$l_v = \left(1 + \frac{i}{r}\right) l \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

Applying similar arguments to the section travelled over in the opposite direction BA, we have :

$$\frac{1}{\eta_i} r\,(P + Q)\,l'_v = -\eta_i'\,(i - r)\,(P + Q)\,l$$

whence

$$l'_v = -\eta_i\eta_i' \left(\frac{i}{r} - 1\right) l \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

a formula that can be used when $i > r$ and $i > J_2$, as previously defined.

If $i < r$ to calculate l''_v, we use the formula (29) in which the term $\frac{i}{r}$ will take the sign : —.

For $i \geqslant J_2$, and using the formula (22), we have :

$$\frac{1}{\eta} r\,(P+Q)\,l'''_v = -\,[\eta'\,(J_2 - r) - 1]\,(P+Q)\,l,$$

whence :

$$l'''_v = -\left[\eta\eta'\left(\frac{J_2}{r} - 1\right) - \frac{\eta}{r}\right] l \quad \ldots\ldots\ldots\ldots\ldots \quad (31)$$

The average virtual length of the section AB as between the journey made in one direction and when made in the opposite direction is given by the following formulæ :

For $i < r$:

$$l_{vm} = \frac{1}{2}(l_v + l''_v) = l \quad \ldots\ldots\ldots\ldots\ldots \quad (32)$$

For $r < i < J_2$:

$$l'_{vm} = \frac{1}{2}(l_v + l'_v) = \frac{1}{2}\left(1 + \frac{i}{r} - \eta\eta'\frac{i}{r} + \eta\eta'\right) l \quad \ldots\ldots \quad (33)$$

For $i \geqslant J_2$:

$$l''_{vm} = \frac{1}{2}\left(l_v + l'''_v\right) = \frac{1}{2}\left(1 + \frac{i}{r} - \eta\eta'\frac{J_2}{r} + \eta\eta' + \frac{\eta}{r}\right) l.$$

The value of J_2 is based on the probable average make up of the trains running over the line

[625 .14 (.73)]

What one year's service on concrete roadbed has shown, [1]

By Paul CHIPMAN,
VALUATION ENGINEER, PERE MARQUETTE RAILWAY.

Figs. 1 to 3, pp. 472 and 474.

(*Railway Age.*)

The experimental section of concrete roadbed installed by the Pere Marquette Railway in December 1926, is 1 326 feet long and is located in the westbound main of a double-track section near Detroit. It consists of thirty-four 39-foot slab sections 21 inches thick and 10 feet wide. In addition to ordinary reinforcing bars a light steel truss is imbedded in the concrete directly beneath each rail. The upper chord of this truss consists of two 1/4-inch by 4-inch steel plates placed vertically with the upper edge slightly below the surface of the concrete. These trusses are connected with each other at intervals by brace frames and adjustable tie rods. Attached to the steel plates at proper intervals are steel stirrups, which afford a means of attaching the rail fastenings. The rails are held in place by clips which are bolted to these stirrups.

The origin of the idea.

Some three years ago Frank H. Alfred, president and general manager of the Pere Marquette, was driving on a new concrete road in Ohio at a point where the highway paralleled an interurban line for quite a distance. At intervals he passed small section gangs laboriously lifting low joints, tamping ties or performing other tasks which a section gang performs day after day, world without end. It started a train of thought in his mind. « If a State finds it economical to do away with good gravel roads and provide a permanent concrete roadway for automobiles, trucks and buses at a cost of $50 000 per mile », he said, « why wouldn't it pay the railroads to do the same thing for their immensely greater tonnage ? » He continued, « It ought to be possible to build a track that would stay put, with practically no expense for maintenance except for renewing the rail. »

The Pere Marquette is watchful of its pennies. It got the habit when they were scarce, in that long, lean period between the passing of the forest and the coming of the automobile. It is the perfect Scotchman among the railroads. But, like the true Scot, it will spend a dollar any time when it is sure of getting two in return — within a reasonable time.

Nothing came of this discussion for some time. During this period Mr. Alfred, in an address at the annual dinner of the American Railway Engineering Association, touched upon the subject in a way that reawakened interest in the minds of many engineers who had given it some thought at one time or another. But now the leaky flues of doubt began

[1] From a paper presented before the Maintenance of Way Club, Chicago, on 21 December 1927.

to dampen the fires of enthusiasm. Would not the impact on a solid roadbed hammer the rail as flat as a pancake and jar the rolling stock to pieces ? Would not the heaving of frost and the settlement of embankments ruin the surface and destroy the track foundation ? In an effort to answer these questions, the history of previous efforts along this line was reviewed, including a study of suggested designs and everything that had been written on the subject.

Fig. 1.

Are rail supporting blocks necessary ?

It was found that the trouble encountered in former experiments, notably those of the Northern Pacific, lay not in the concrete foundation, but in the blocking that was used to separate the rail from the foundation. Naturally the question arose, « Why make such a separation ? » The only answer was that it had always been done. True, J. W. Shaub, in 1899, proposed a design in which the rails would rest directly on longitudinal stringers of concrete and quoted Col. H. G. Prout as follows :

« I am inclined to think that, if the roadbed could be made absolutely unyielding, the springs of the vehicles providing the elasticity, the best results would be had. If the track could be as smooth and relatively as stiff as a planer bed there would be a saving in the cost of maintenance of track and machinery and in coal consumption. The stiffer the rails, the less the creeping due to the wave which runs ahead of the wheels, the less the wear of the ties due to this motion, the less the destruction of the track and running gear due to the pounding of the wheels and the easier the hauling of the trains. »

But Mr. Shaub evidently came to the conclusion that this was too radical a departure from existing standards, for in 1907 he proposed another design in which cross ties and ballast were used, the end of the ties being supported by steel I-beams, placed longitudinally, which also served to retain the ballast. He proposed that later the I-beams be removed and the ballast replaced with a concrete slab; but had evidently given up the idea of placing the rails directly on the concrete, for he said that the « superstructure should be some form of longitudinal support bedded in concrete so as to distribute the loads over large areas, offer perfect drainage and be absolutely unperishable and unyielding ». Even the Portland Cement Association

worked out a design in which the rail was supported on wooden blocks. Since Mr. Shaub's defection, nobody had the temerity to propose that the rails rest directly on the concrete. Opinion appeared to be unanimous that there must be a cushion of some resilient material between the rail and the concrete to lessen shock due to passing loads and prevent deterioration of the concrete base, battering of the rail, and injury to rolling stock. True, some street railways were using girder rails resting on concrete; but this was a different condition, where loads were much lighter and the rails, in addition to resting on concrete, were completely imbedded in it.

As we studied the subject, the conviction grew that there was a confusion of thought in this matter. It had been assumed that the shocks and jars experienced when a train passes over ordinary track would still exist on track of a rigid type; and that due to such rigidity the damage to track and equipment would be greater. The conclusion was correctly drawn, but we doubted the major premise. On a perfectly smooth and rigid track, why should there be any shocks? If no shocks, why should there be any hammering of rail and roadbed? Furthermore, by supporting the rail rigidly throughout its length the rail-wave, with all its attendant evils, would be banished. But would the conocrete stand the strain? Why should it not? Surely, a 90-lb. rail could be counted on to distribute its load evenly over a longitudinal distance of 10 inches thus giving 50 square inches of concrete to support 30 000 lb., or a pressure of 600 lb. per square inch or, allowing 50 % for impact due to counterbalance, a pressure of 900 lb. In these days of 5 000 lb. concrete, that did not seem out of reason, especially when it is realized that compression tests of concrete are made by applying pressure to the ends of short cylinders, and that the strength of concrete under a load applied to a limited portion of its surface has never been determined, although known to be much higher than that shown by the standard tests.

Is a rigid track construction practical ?

Past experience indicated that a cushion of wood or other resilient material would become a continual source of uneven track and expense for renevals. Further, it did not do away with the rail wave, which would no doubt lose some of its customary vigor, but would still be much in evidence. It became more and more apparent that the advantages of a permanent roadbed could not be obtained unless a rigid type of track were proven to be practicable and that the primary purpose of our experimental installation, if made, would be to determine this point.

The problem then was to construct a support for the rail that would be wide enough to so distribute the load as not to exceed the bearing power of rather soft soil and of such strength as to span safely any very soft spots of ordinary size; to produce a rail seat that would be in as nearly perfect line and surface as it could be made; to design adequate rail fastenings; and if possible, to devise some means by which the concrete slab could be restored to its original elevation in case of pronounced settlement of the embankment.

There was one point on which we had serious misgivings, due largely to our experience with some concrete ties installed for experimental purposes at Saginaw about 25 years ago. In a few of these ties the rail rested directly on the concrete. These ties are still doing service; but, although they are otherwise in good condition, the rail has cut down into the concrete an inch or more and has come to rest on the steel reinforcing bars. Would the same thing happen on a slab where the rail was continuously supported and not subject to any consi-

derable vertical movement ? Would the effect of repeated shock and the small amount of vertical and lateral motion, which cannot be absolutely eliminated, be to abrade the concrete very slowly and cut a groove beneath the rail? Prob-

Fig. 2. — A view of the finished track.

Fig. 3. — A « close up » of the rail fastenings.

ably not, but we were afraid to take a chance and thought it desirable to provide a metal seat for the rail.

This feature and the necessity for some means of providing a rail seat that could be set to exact line and surface and be kept there while concrete was being poured, led to the adoption of the light trusses under each rail. A width of 10 feet was decided on and a thickness of 18 inches later increased to 21 inches. The bolt and clip were chosen as the most practical rail fastening, as it was considered important that the rail be held tightly to the base. The bolts placed head up, were to be held by nuts placed in the concrete below a stirrup which engaged the two steel plates which formed the upper member of the truss.

President Alfred thought that if our ideas were submitted to the engineers and railroad men of the country through the medium of the technical press, we might receive some helpful criticism and at any rate arouse an interest which would result in other experiments along this line. Accordingly this was done. (See *Railway Age* of 12 December 1925, page 1083.) (1). The Portland Cement Association assisted by broadcasting a reprint of one of these articles and asking for comment thereon. A considerable amount of interest was shown.

But the result as to constructive criticism was disappointing. Two or three thoughtful studies of the subject were made, but the net result in the way of new ideas was practically nothing. Adverse comment was frequent, and as might be expected, the main point of attack was the lack of flexibility. The chief engineer of one railway wrote: « I do not consider this a practical design. » This was, of course, very helpful. One thing that did result, however, was a deluge of communications from cranks of varying degrees of sanity, whe asked for opportunity to try out their ideas on the Pere Marquette. Most of these schemes were devised by persons who had no knowledge, practical or theoretical, of

(1) See *Bulletin of the Railway Congress*, number for August 1926, p. 673.

the requirements of track structure or appliances or how these requirements could be met.

Experimental installation decided on.

It was now definitely decided that an experimental section would be installed. The design was modified slightly, not on account of any helpful suggestions which we had received from outside, but because we had come to realize that the real object of our experiment was to prove a principle and not to test the adequacy of any design. It was to settle the question whether or not a rigid track is practical. We felt that if it could be proven that flexibility was not essential to a track structure, a design would eventually be worked out by somebody that would meet the requirements. Economy of design was therefore a secondary consideration; but it was of the utmost importance that we take no chance in this initial installation of having a failure that would discredit our proof, if such were obtained, of the practicability of rigid track. Even though such a failure might have no relation to this predominant problem, it would be sufficient proof to the prejudiced or unthinking of the impractibility of any radical change in the present type of track. With this in mind, the thickness of the slab was increased to 21 inches and the amount of reinforcing metal was materially increased. The materials were now ordered, the most favorable location that we could find was selected and we prepared for construction.

When construction began, a number of things were learned. About the first one was that our steel trusses were not true enough to serve as rail seats. We found that the concrete could be finished to a truer surface than that afforded by the edges of the steel plates. It was therefore decided to finish the concrete about 1/8 inch higher than the steel. It was also found that these trusses were not in as true a line as was required for our rail fastenings, so that it was necessary to line them up with heavy angle bars bolted to the surface. When the design was made, no particular attention was given to the installation of the rail; but the location finally decided on was in block signal territory. The design we had adopted could scarcely be improved upon as a means of dissipating any electric current in the rail. It was necessary to provide means of insulation.

This was well taken care of as to the rail clips by means of fibre plates and bushings, and as to the rail seat, our 1/8 inch of concrete between the rail and steel plates was helpful. It was anticipated, however, that this would not afford sufficient insulation, as there would be a few places where the steel would be very close to the surface. Furthermore, a rail might in the course of time, wear down into the concrete so that it would be in contact with the steel plates at many places. It was therefore expected that eventually it would be necessary to use a sheet of insulation fibre under the rail. As an experiment, however, an asbestos felt and asphalt composition known as fibrerock was used.

The pouring of concrete was not begun until early in November. Before the work was finished on 2 December, there was some rather cold weather, which made it necessary to heat the water and at times the sand. The mixing and placing of the concrete was under the supervision of the representatives of the Portland Cement Association, who also relieved us of the keeping of records, as they maintained a record system which covered all features of the work, including a very complete series of photographs. Three test cylinders were made from the concrete used in each 39-foot section. The excellence of the concrete, due in a large measure to this careful supervision, is proven by the results of these tests. The instrument work involved in securing a true and correct

line and surface for the rail seat and fastenings was quite exacting.

Laying rail at the west end began shortly before the completion of the concrete work at the east end. The first train was put over on 19 December. A speed limit of 30 miles per hour was maintained during the winter and early spring, after which time it was raised to 45 miles per hour.

Observations from the first year's use.

What conclusions are to be drawn from the first year of operation, which was concluded two days ago? First, in regard to the main question, whether a rigid roadbed is practicable or whether a railroad track must have more or less flexibility, I think we may say that the practicability of a rigid roadbed, provided it is also a smooth one, has been proven beyond a doubt. A year's traffic has not resulted in any disintegration of the concrete beneath the rails nor in any undue battering of the rails themselves. The effect on rolling stock cannot, of course, be determined definitely by a test section, a quarter of a mile long; but a ride over this section is enough to bring the conviction that there can be no bad effect. The train glides along so smoothly that one feels, with the elimination of the wear and tear due to the ups and downs of ordinary track, that a considerable saving in maintenance of equipment may be anticipated.

On the receiving rail at the 68 joints, the amount of batter, as defined by the Committee on Rail of the (American Railway Engineering Association), is as follows: one joint has a batter of 3/64 inch; 9 joints have a batter of 1/32 inch; 16 have a batter of 1/64 inch, and in 42 the batter is too small to measure. It would be hard to find a piece of ordinary track in use a year, under like traffic, that would show a better record. There are, however, a number of joints with a type of rail batter which is not so common on ordinary track. Here, the receiving rail is not battered at the end, but from 2 to 6 inches from the end a slight depression begins which varies in length from 6 to 18 inches. Under the A. R. E. A. definition, this would not be classed as batter, as this definition calls for the use of a 12-inch straight edge and measures the batter by the distance between the surface of the rail and the straight edge at a point 1/2 inch from the end of the rail.

In my opinion, this type of batter is due to the delivering rail being slightly higher than the receiving rail. It takes 1/32 of a second for a body to fall 1/64 inch. In that time a wheel moving at the rate of 30 miles an hour would be about 16 inches from the joint, at which point the wheel would strike the rail. It hardly seems possible that the impact due to a fall of 1/64 inch would have any effect on the rail surface; but when we consider the enormous compressive stress developed in the small area of contact between the wheel and the rail under normal conditions, it is easy to believe that the additional stress due to impact would result in some distortion of the rail surface. The indications are that there will be very little battering with this type of roadbed, except that due to inequality in the heights of adjoining rails. If this proves to be the case, grinding the high rail may prove advantageous. However, observation of the end of the delivering rail inclines one to the belief that batter of this type tends to correst itself by the wearing down of the delivering rail, and that after a certain stage is reached, its progress will be slow.

In finishing the concrete rail seat no attempt was made to perfect the finish on any portion that would not lie immediately beneath the rail. This resulted, at places, in a slight ridge just outside of the rail seat, which makes it hard to be certain that there has been no abrasion of the concrete under the rail;

but the fact that such apparent depression occurs only for short distances indicates that it is due entirely to the way in which the rail seat was finished, as the conditions which would cause wear are practically the same throughout, both as to the quality of the concrete and the motion of the rail. If, in the course of time, abrasion develops, it will prove the necessity for providing a metal bearing for the rail, as was done in the present installation. If it does not develop, the design can be simplified accordingly.

Some settlement has appeared.

The other question of major importance is whether or not a roadbed of this type will retain its original smoothness. After the first year's operation, our test section rides as smoothly as at the start. Levels taken from time to time show that while there was a slight and gradual settlement for a time, it was fairly uniform over the whole installation. Levels were taken on 14 December 1926, five days before operation began and on 30 December 1926, eleven days after operation began; also on 9 February, 12 April, 25 August, and 12 December 1927. These levels were taken at the ends of each of the 39-foot sections, a reading being taken adjacent to each rail. On 30 December 1926, the minimum settlement was zero and the maximum settlement was 0.08 foot. The greatest variation in 39 feet, the length of a section, was 0.04 foot, but in most cases the change in this distance was only 0.01 or 0.02 foot. The greatest difference between two rails at any point was 0.02 foot and in most places there was either no difference or 0.01 foot. The average settlement after 11 days of operation was 0.038 foot, being the same for both rails. On 12 December the maximum settlement was 0.12 foot, the minimum 0.03 foot, the other measurements showing no change. Readings were only taken to hundredths of a foot, as the roughness of the concrete surface made it impractical to attempt greater precision. Many of the apparent differences of 0.01 foot between the rails are also due to this fact.

As a whole the roadbed settled 0.038 foot in the first eleven days after operation began, an additional 0.037 in the next six weeks, and 0.015 in the following two months. Practically no settlement occurred after 12 April.

The amount of this settlement is rather surprising. The west half of the section was built over what had been a very shallow excavation, and the same is true of the south side of the east half. The north side of the east half was over a light embankment of sand varying in depth from nothing to 2 1/2 feet. The side over the fill has not settled any more than the side over the cut. The bottom of the slab was level with the bottom of the old ties, to that the ballast under the ties was not disturbed. Evidently, the ballast was driven down into the subgrade, as after three years of traffic, the ballast must have been fully compacted. It is well known that this action occurs in the case of ordinary track, but it was hardly to be expected under a continuous slab. The other surprising feature about this settlement is its uniformity. The variation in settlement is so gradual that it has had no effect whatever on the riding quality of the track. It is not likely that this installation will ever call for lifting any of the slabs in order to restore the old grade.

Last winter was rather mild and it is not probable that there was much, if any, frost under the concrete. With the thorough drainage provided by placing the concrete on top of the old ballast and by laying a tile drain close to the inner edge of the slab, it is doubtful if there would be any heaving during the most severe winter that may be expected in this latitude. This, however, is one of the things that is yet to be demonstrated.

Concrete is in excellent condition.

The concrete is in excellent condition. In slabs numbers 1, 11, 33 and 34, hair cracks have appeared which extend the full width of the slab. In slab 1 this marks a construction joint located about 10 feet from one end, delays incident to starting the work having made it impossible to finish this slab on the first day. Slabs 33 and 34 were laid in very cold weather, although this may not be the reason for the cracks. None of the cracks show any indications of widening, and levels fail to show any deflection at or near the cracks. It was expected that some such cracks would appear. With the exception of slab 1 they are all near the center of the sections in which they occur.

When operation began, the rail on the east approach started creeping westward in the direction of traffic and pushed the rails on the concrete forward until the joints were closed for several hundred feet. The rail was put back in place and the approach thereby anchored; since that time there has been no trouble with creeping. The maximum movement has probably not exceeded 3 inches.

The sound made by a train passing over this section is different from that on ordinary track. There is a rumble that has a touch of metallic clang, probably due to the reflection of the noises made by wheels and trucks from the surface of the concrete. However, there are no clicks when the wheels pass over the rail joints. Probably the sum total of the noise is no greater than on ordinary track, although its quality is different.

Some possibilities for improvement

Our experience with this section has brought to light a number of ways in which the present design can be improved. The fibrerock which was placed under the rail was found to be unsuited for the purpose. This material has little strength when saturated with water and in spite of its asphaltic content, is quite absorbent. After becoming wet the edges dry before the center, and the lateral motion of the rail is sufficient to split the material and cause it to work out at each side of the rail. After this happened, trouble was experienced with signals after a rain. This trouble was found to be, for the most part, near the west end, where in two or three places the steel plates came close to the surface. This was relieved temporarily by blocking the rail up on small pieces of insulating fibre, but trouble was still experienced during and after rains. Within the next few days a strip of insulating fibre will be placed under one rail for the entire length of the section. The whole problem of insulation can be solved by so changing the design that the rail will not be in contact with or close to any other metal which would convey current to the ground or to the other rail. If it is necessary to provide a metal bearing for the rail, such bearing must not be connected with any tie rods or reinforcing bars.

It is possible to simplify the design by doing away with all fabricated steel and using ordinary reinforcing bars, thus making a very large reduction in the cost. It is also probable that both the concrete and reinforcement can be so disposed as to result in a considerable saving in the amount of each, without reducing the strength. A width of ten feet is more than necessary, but probably nine feet is about the minimum width that should be used.

I believe that our experience with this roadbed would be sufficient to convert any person who had been opposed to the canting of rails. It is unfortunate that this was not done on our experimental section. After a year's service, parts of certain rails are not much more than half converted, owing to the rail not being canted. Such batter as has taken place is much more pronounced on the inside of the rail.

One feature, the importance of which was realized when this section was built, has received added emphasis from our experience. This feature is the importance of having as close a contact as possible between the base of the rail and its support and of maintaining this close contact by keeping the bolts which fasten the rails to the roadbed tight. It is important to reduce both vertical and lateral movement of the rail to the lowest possible limits. Three quarter inch bolts were used for this purpose, but they should be 7/8 inch or possibly 1 inch. A small number of these bolts have failed by the heads snapping off. This is more apt to occur in cold weather. Nut locks were used under the boltheads to relieve the shock due to sudden lifting of the rail at points where the surface of the rail seat is a little lower than it should be, but these do not seem to accomplish their purpose fully. Nearly all of these failures were at the ends of the section where it joins the ordinary track construction, and were evidently due to the greater vertical motion of the rail at those points. The failures, at other places were, in part, at least, due to defective bolts.

In conclusion, we feel that much has been accomplished by this experiment. The main point at issue, — that a rigid track is entirely feasible and results in no damage to the rail or rolling stock — has been proven. We have learned many things which will be of great value in making plans for another test section to be installed during the coming year. We firmly believe that before many years have passed a design will be developed that will be entirely satisfactory and at a cost that will, in the case of roads of heavy traffic, be justified by the savings that will ensue.

Doubtless a considerable saving will result on account of the reduction of train resistance, but it is our belief that a much larger saving will be made in the cost of maintaining track and equipment. Aside from expense incurred in correcting patent errors in design, such as the insulation and bolts referred to, there has been no expense for maintenance on this section.

No attempt has yet been made to determine the difference in tractive effort on this section and on ordinary track. The section is too short to make any conclusive investigation with a dynamometer car. Something might be done by measuring the retardation of drifting cars, but so many observations would be required to get conclusive data that it has not been attempted.

Time and further experiments will be required to develop the best design and to ascertain the economies that will result. It is the intention of the Pere Marquette to continue such experiments. If other railroads would do the same, it would reduce the time necessary to develop a thoroughly satisfactory design.

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The use of colonial timber for railway sleepers.

(*Les Chemins de fer et les Tramways.*)

Before the war France imported more than 300 million francs' worth of timber of all kinds (principally oak and pine), for the most part from Scandinavia, Russia and Austria. A very small proportion of the timber imported was used for railway sleepers, as our own resources in this connection were practically sufficient to satisfy our requirements.

The war, however, by causing us to

use more than 60 million cubic metres (2 118 000 000 cubic feet) of wood, has made it necessary for us to import timber, with serious effects on our rate of exchange. In addition, the pre-war stocks of sleepers were used up in the construction of numerous strategic lines. The destruction by the enemy of large sections of railway made it necessary for us to reconstruct them. As during five years the maintenance of our railways had been sadly neglected, extensive renewals have been necessary since 1920 over the whole French railway systems. Finally, the national network of railways has been augmented by the Alsace-Lorraine lines, whose timber requirements were far from negligeable.

Our consumption of sleepers thus increased considerably during the years of the war as compared with pre-war years. As, further, we were deprived for five years of the use of some of the finest of our northern and eastern forests, which moreover were systematically cut by the enemy, we found ourselves in a difficult situation after the war. The prices of sleepers underwent a serious increase, whilst at the same time the difficulty of procuring sufficient supplies became greater and greater.

In order to remedy this situation an organisation was created, known as the Central Timber Office, one of its main functions being to distribute among the different railways the supplies of sleeper timber available from the various sources, so as to avoid the danger of competition between the large companies, the only result of which would have been to provoke a rapid increase in prices.

This measure was insufficient, and it appeared that an excellent method of reconstituting our stocks and covering the whole of our increased requirements would be to make use of timber from our colonies.

The ressources of our colonial forests.

Including Alsace-Lorraine, the forests of the mother-country now cover an area of 10 million hectares (24 700 000 acres).

Our colonies have a wooded area of some 100 million hectares, made up as follows :

Africa	65 000 000 hectares	(160 600 000 acres).
Indo-China	25 000 000 —	(61 800 000 —).
Guiana and the Antilles	5 200 000 —	(12 800 000 —).
Total	95 200 000 hectares	(235 200 000 acres).

From the point of view of their utilisation, these forest constitute two groups, one of 65 million hectares in Africa, the other of 30 millions scattered about the earth at places far distant from the mother-country.

From the point of view of meeting our requirements, only the first group is of interest owing to its relative nearness to the mother-country. The utilisation of the second group can scarcely be considered feasible except for the requirements of the colonies themselves (the railways of Indo-China, for example, as regards which M. Varenne has recently drawn up an extensive programme of development, which relies in great part for its fulfilment on the contributions in kind available under the Dawes plan), and for increasing our exports.

It is above all to our forests in equatorial Africa that we must turn. These may be divided into three main groups :

Ivory Coast	12 000 000 hectares	(29 700 000 acres).
The Gaboon, Congo, Oubanghi	30 000 000 —	(74 100 000 —).
Cameroon	13 000 000 —	(32 100 000 —).
Total	55 000 000 hectares	(135 900 000 acres).

Determination of varieties of timber suitable for use.

Timber which is to be used for sleepers must fulfil the following essential conditions :

1. Resist causes of decay (damp, fungi, etc.) ;

2. Be hard without, however, resisting the penetration of the antiseptics used to ensure its preservation. The resistance of the timber to crushing determines the ability of the sleeper to support the weight of trains without either breaking or splitting;

3. Be able to stand drilling and dowelling without splitting or crumbling, so as to ensure the rail being properly secured;

4. Be sufficiently elastic to afford smooth running;

5. Be homogeneous, that is to say, any one variety of timber must be constant in quality, so that the track may be consistently well laid throughout its whole length.

It has been necessary to carry out tests with a large number of specimens in order to discover which of the extremely numerous varieties of timber from the equatorial forests are the most suitable.

A start was made by limiting the tests to varieties of timber recognised *a priori* as analogous to other colonial varieties already used on certain railways, such as Jarrah and Karri, which are imported from Australia for the construction of railways in India. At the same time, interesting data was obtained by examining buildings constructed by the natives with these varieties of timbers (huts, pile-work, etc.).

Methodical tests were carried out with a view to determining the hardness, the wear and the mechanical and elastic resistance of the wood.

The most important tests had to do with the resistance offered by the wood to the tearing out of the coach screws. These tests are made by means of the « extractometer », and varieties of timber have been discovered which offer a resistance to tearing out exceeding 8 000 kgr. (17 600 lb.).

Tests are also made to determine the behaviour of the wood when being manufactured (sawing, adzing, drilling, dowelling), its penetrability by water and preservatives, and its tendency to split in hot weather or when driving the holding down screws.

Durability is tested by burying the wood specimens in horse manure so as to cause heating. The specimens are uncovered at the end of each summer, and careful note is taken of the manner in which they are supporting the test. The process is continued until it is thought that the specimens have been thoroughly attacked by rot. Such tests, however, take years to complete, and it is essential that the experimenters should be highly conscientious in the performance of their duties and should possess real powers of observation.

The tests referred to above have established the qualities of various kinds of wood, as follows :

Azobé (Ivory Coast). — Very hard wood, difficult to saw (the saw does not bind), gives in general a clean cross cut; the very close annual rings show how compact and hard the wood is. It is very difficult to drill and adze, the adze fetches off the wood in small chips, and dowelling is difficult. The wood is not easily penetrable by the chemicals used for its preservation. In general, therefore, this wood has great resistance, will make sleepers of long durability, but necessitates the use of specially hard tools.

Bodo (Ivory Coast-Gaboon). — This wood is a little harder than oak, and binds slightly during sawing.

Water penetrates readily, particularly at the ends, and it is therefore necessary to creosote it very thoroughly to protect it.

Bilinga (Ivory Coast - Gaboon - Came-

roon). — A very hard and heavy wood, giving a very fine sawdust; has many characteristics in common with oak, and makes very good sleepers for main lines.

Nyouré (Gaboon-Cameroun). — Semi-hard wood which may be classified as between beech and fir. The adze fetches off the wood in small chips and splinters; it is fairly easily drilled, although it crushes under the action of the auger. It somethimes splits in dowelling, but is not easily penetrable by water. It makes good average sleepers.

Okoumé (Gaboon). — An excellent wood and one of the best known, having already furnished many sleepers for various railways.

N'goué (Gaboon-Cameroon). — Hard and heavy wood, in which the sapwood is almost as firm as the heart-wood; has certain points of resemblance to beech. Adzing produces quite short chips; drilling with the auger is difficult. This wood makes good sleepers of long durability.

Identification of species.

The great difficulty experienced in using colonial timber consists in the lack of certain knowledge as to the exact nature of the different species. The native names vary from one region to another for one and the same tree, and it is very difficult to identify exactly the trees felled.

A start has been made with the drawing up of lists and classifications, indicating the main characteristics of certain species. Professor Perrot has already completed the classification of several species, after carrying out a series of mechanical and physical tests on different specimens in order to ascertain their density, colour, resistance to compression, bending and splitting, the facility with which they can be dried, their durability, etc. We give below an example of his classification sheets (Gaboon mahogany).

In order that the identification of the wood may be absolutely conclusive, it is necessary to examine it on three different faces : transverse, radial and tangential. For this purpose typical specimens must be available at the various colonial timber markets and at the French ports of arrival (Bordeaux, Marseilles and, in particular, Le Havre), these specimens being in the form of trapezoidal prisms presenting the three required surfaces; it is even necessary also to take transparent sections for differential examination under the microscope.

In order to build up a complete collection of specimens with a detailed study of the species represented, it is necessary (to quote the programme laid down by the Association « Colonies-Sciences », which is closely interested in this subject) :

1. To study in all the colonies, but first of all in the equatorial and tropical forests of Africa, from the Congo to Liberia (the study of African timber being the most urgent), the distinctive morphological characteristics of the commercial kinds of timber, their habitat and the quantity available;

2. To select with great care specimens of the wood, and its twigs and leaves, flowers and fruit;

3. To determine from these specimens the botanical classification;

4. To group, dissect and classify the specimens to permit of their physical, static, dynamic, technical and macroscopic study;

5. To effect scientifically on the specimens thus prepared, the physical, static and dynamic tests;

6. To study transverse, radial and tangential sections under the magnifying glass, with the aid of sketches or photographs;

7. To work up the different kinds of wood in the workshop, and to study them therein from the technical point ot view;

8. From the observations thus made to determine the qualities of each kind of wood, and subsequently the practical

consequences of converting the trees into log in the rough in the colonies, of its transport, of its utilisation and conversion, and on the tools as well as the method of finishing to be used with by each wood;

9. To co-ordinate and publish the results of these investigations.

The complete study of a given variety of wood must indicate the following :

- Names . . . .
  - Commercial.
  - Scientific.
  - Colloquial.
- Habitat . . .
  - Region.
  - Nature of soil.
  - Manner of growth.
- Abundance. .
  - Frequency.
  - Cube per cent.

Native uses.

Forest growth and treatment.

- Morphological characteristics and botanical description.
  - Comparative height and girth (photographs).
  - Root.
  - Trunk.
  - Bark.
  - Crown (specific and forest form).
  - Leaf.
  - Flower.
  - Fruit.
- Principal characteristics.
  - of bark.
  - of sapwood.
  - of heartwood.

a) Macroscopical study of transverse, radial and tangential sections :

- For each section.
  - Cellular tubes.
  - Medullary rays.
  - Fibre.
  - Woody parenchyma.

With photographs and sketches.

- *b*) Chemical characteristics.
  - Durability.
  - Gum and resinous matter.
  - Colouring matter.
  - Tanniferous matter.
- *c*) Physical characteristics.
  - Average specific weight.
  - Grain and texture.
  - Colour.
  - Odour.
  - Taste.
  - Porosity.
  - Hardness.
  - Shrinkage.
  - Hygroscopicity.
- *d*) Mechanical characteristics.
  - Resistance to crushing.
  - Toughness.
  - Resistance to bending.
  - Resistance to tensile stress.
  - Resistance to blows.
  - Resistance to shearing and splitting.
  - Hardness tested with the Janka ball.
  - Coefficient of shrinkage.
  - Grain.
  - Coefficient of flexibility.
- *e*) Technical characteristics.
  - Cohesion of fibres, fissility.
  - Retension of nails, screws, spikes.
  - Resistance to action of tools :
  - 1° To longitudinal and transverse cutting and splitting; in the case of standing timber, to the felling saw.
  - 2° To the saw : circular, band, frame.
  - 3° To the plane.
  - 4° To dovetailing tools.
  - 5° To the drilling machine.
  - 6° To the moulding machine and tools.
  - 7° To the lathe.
  - Glueing.
  - Colouring.
  - Polishing.
  - Varnishing.

Use of the wood.	Suitable uses.
	Cutting up.
	Classes of steel, kinds of blades and teeth to be used.
	References.
Commerce.	Preparation for commerce.
	Standard of quality per variety, logs.
	Markets and outlets.
By-products.	Food for human consumption, oils.
	Medicaments and drugs.
	Tannin.
	Gums, resin, rubber, gutta-percha.
	Textiles.
	Ornamentation.
	Results of analyses.

Identification tests are at present in progress on the above bases at the experimental station of the Colonial Garden at Nogent-sur-Marne, where classification sheets have already been prepared, the most important of which relate to the following species : Mahogany, Bossé, Avodiré, Okoumé, Limbo, Bilinga, Bahia, Padouk, Mowingui, Niové.

Photographs of cross-sections, slightly enlarged, are taken for transmission to the railway agents stationed in the various timber regions, so that with the aid of a magnifying glass they may be able to identify the timber with which they have to deal.

As a result of the various tests carried out, the railways have drawn up the following list of woods which they have decided to use for sleepers :

Identification No.	Commercial name.	Botanical name.
6	Bilinga.	*Sarcocephalus trillesii.*
4	Eveuss.	*Klainedoxa latifolia.*
24	Miama.	*Calpocalyx Klainei.*
3	Niové.	*Staudtia gabonensis.*
1	Ozouga.	*Saccoglottis gabonensis.*
2	Alef.	*Irviagia obléaga.*
5	Tali.	*Erytrophleum guineense.*
26	Padouk.	*Pterocarpus Soyauxil.*
25	Coula.	*Coula édulis.*
16	Tsoumbou.	*Pippadenia* sp. ou *Newtonia.*
15	Dina.	*Dailium* (rel. to. *Connarbides*).
28	Ebornzok.	*Unclassified leguminosa.*
9	Azobé.	*Lophira procéra.*
23	Mowingui.	*Disthemonantus Benthamianus.*

The foresty consortium.

In order to co-ordinate their efforts with a view to the rational exploitation of the concessions granted to them in the Gaboon, the French railways have formed a consortium which has erected large saw-mills in that region, together with numerous accessories, such as workshops, dwelling-houses, gardens, pumping stations, railway lines, boats, hospitals.

Making of sleepers.

The cutting of sleepers can conveniently be done in the colonies. They are more or less of a single type, and the natives can make them easily and accurately. The wood is first of all cut up into thick planking by the vertical saw, then the sleepers are cut out by the circular saw. The sleepers are easily handled, transported and stowed aboard ship.

There was long hesitation before it was decided to carry out the sawing and squaring of the timber on the spot. It was in fact considered that these operations necessitated the installation of expensive and delicate machinery and tools, difficult to repair on the spot in case of breakdown, and requiring a specialised staff who would only accept the posts at very high rates of remuneration. The colonial timber was, therefore, brought to France in the form of round log or dressed log.

It has now been recognised that in view of the high cost of transport, it is inexpedient to transport waste material. The unsquared logs are of large dimensions, and their handling, stowing aboard ship and unloading at the port of arrival is both difficult and expensive. Further, it was often discovered on arrival that the logs were unfit for use, as owing to the presence of the bark it had not been possible to detect flaws or disease in the wood, which would have been detected if the trunks had been sawn up previously.

Numerous saw-mills have, therefore, been erected in the colonies since the war, thereby following the example set by the Germans in the Cameroon.

The railway consortium has installed its saw-mills at the centre of its concession, so as to eliminate superfluous transport. It is in certain cases, however, more convenient to instal the mills on the coast at the port of lading, where labour and supplies are more easily obtained.

The work consists principally in converting large butts, for the trees felled are very straight and tall, of considerable diameter, and tapering only very slightly. The branches are few and full of knots; they are broken up by the fall of the tree, and are used for firing the boilers which run the machinery of the saw-mills.

The colonial saw-mills endeavour to reduce the number of sawings to a minimum, in view of the lack of initiative and intelligence shewn by the native labourers. It is essential that the labourer should have only one type of cutting operation to perform. He then acquires a certain machine like skill which makes it possible to rely on the regularity and accuracy of his work. All that is necessary then is to give him his quota of timber, indicating the dimensions of the cuts to be made, and never to vary his task.

Ordinary permanent way sleepers can be cut perfectly well in this manner. The butts are first cross cut, then cut up into scantlings by means of multiple frame saws. It is estimated that the cut wood produced by a colonial saw-mill is equivalent to about half the quantity of untrimmed timber felled. A forest producing 100 000 cubic metres requires therefore, a saw-mill capable of an output of 50 000 cubic metres, and for this it is necessary to have round about 1 000 H. P.

The tools must moreover be particularly strong. The saws have ordinarily to cut up trunks measuring two metres (6 ft. 6 in.) in diameter. Use is often made of frame saws with multiple side blades. Although somewhat slow, the work of this saw is regular and perfectly accurate, provided the adjustment of the parallel blades is maintained by means of suitable wedges.

Use is also frequently made in the colonies of Canadian saws with interchangeable teeth. They work easily and rapidly with certain kinds of wood, such as Niové, Bilinga and Okoumé, and for thicknesses of not more than from 14 to 18 cm. (5 1/2 to 7 inches), which corresponds to the thickness of sleepers. In the case, however, of hard varieties of wood, the interchangeable teeth wear out rapidly, and the procuring of new supplies from America is difficult and expensive. An ingenious arrangement has been devised by M. Noyon, head of the technical service of the consortium, to improve the output of these Canadian saws when working on hard varieties of

timber. The arrangement consists in inserting pointed teeth between the ordinary teeth of the blades.

The *colonial saw-mills* will thus comprise :

1. A series of log frame saws with gangs of saw blades, capable of cutting up the butts into logs and converting the logs into scantlings. These saws cut at a speed of from 30 to 40 cm. (12 to 15 inches) of timber per minute;

2. Circular saws for cutting up the scantlings, and for cross-cutting trees of smaller diameter (average of 80 cm. [2 ft. 7 1/2 in.]). Their average speed is from 25 to 30 cm. (10 to 12 inches) per minute for logs, and from 40 to 50 cm. (16 to 20 inches) per minute for scantlings.

All the saws will have suitable teeth for cutting up the different kinds of wood which vary from the softest to the hardest. The toothed edge will be of an average type, and sufficiently simple to allow of its being sharpened mechanically — the only possible arrangement in view of the lack of skill shewn by the native labourer. In the case of the Canadian saws, in which the blades are fragile and expensive, the precaution will be taken of increasing the diameter of the supporting discs as much as possible, so as to ensure the rigidity of the blade on the spindle.

Further, use will be made of portable machinery, so that it may be possible to cross cut the trunks at the spot where they are felled, so as to facilitate the transport of the very large butts. This machinery should for preference consist of frame saws, with a thick blade inclined so as to cut only on the back stroke. This blade is provided with a guide to prevent lateral displacement. The butt is held by dogs while it is being sawn up.

Net costs.

The price of sleepers made from colonial timber is affected by the cost incurred in organising the forestry concessions and in preparing the timber by specialised labour. These prices are still too high.

In order to reduce them it is necessary:

1. To improve the methods of working the colonial forests;

2. To organise the conservation of the forests by creating a forestry staff as is done in France, so as to avoid the error of felling trees hapharzardly, and then of using only the best kinds, the result of which will be their ultimate complete disappearance from the equatorial forests;

3. To encourage the recruiting of native labour, and to combat the epidemics (yellow fever) by which the natives are decimated;

4. To multiply the means of transport between the interior and the coast by the building of roads and railways and the organisation of river transport;

5. To facilitate the loading into ship, transport by sea and the unloading of the timber. For this purpose, at colonial ports where there is no close anchorage for ocean-going steamers, and where transhipment from small craft is consequently necessary, wharves must be constructed so that the timber may be loaded directly on to the ships by mechanical means. As regards unloading at French ports, the port authorities at Le Havre have recently decided to instal a special stacking ground with six gantry cranes, provided with cranes running on four parallel tracks. The butts are stacked under the crane at the openings. One jib of the crane serves a roadway and the other the railway so that railway wagons or motor lorries can be quickly loaded. It is anticipated that this installation will be capable of dealing with 100 000 tons of timber per annum;

6. To improve the methods of preserving the wood;

7. To make better use of the by-pro-

Example of classification sheet prepared by Prof. Perrot.

GABOON MAHOGANY.

Meliaceæ.

This wood corresponds to specimen No. 26 520 in the Aug. Chevalier collection.

It differs appreciably from the other mahoganies, but must be related either to the genus *Khaya* or the genus *Entandro phragma*, meliaceæ, which produce the African mahogany,

Usual description or native name	Gaboon mahogany: *ombega*.
Scientific name	*Khaya anthotheca* A. Chev.
Family	Meliaceæ.
Origin	Gaboon Chevalier coll. nº 26520.

Microscopic examination.

Principal characteristics of the wood.

Aspect : fibrous.		Hardness : fair.
Grain : rather coarse.		Density : 0.705.
Colour : rather deep red.		Soaked in water : rosy yellow.
Odour : nil.		Soaked in alcohol : clear reddish brown.
Porosity : average.		Soaked in alcohol plus water : No reaction.

Special remarks : Wood resembling *Khaya ivirensi*, with fibrous bands more or less irregularly sinuous.

	Transverse sections.	Tangential seotione.
Cellular tubes	Distribution.	Generally isolated.	...
	Number per square millimetre	5	...
	Diameter.	Generally from 150 to 200 µ, the most voluminous, 300.	...
	Shape.	Slightly oval or elliptical.	...
	Thickness of cell walls..	Thin.	...
	Nature and appearance of punctuation	...	Rounded, very fine.
Medullary rays	Height	...	Up to 900 µ.
	Width in µ.	...	Up to 150 µ.
	Number of cells in width	...	6 to 8.
	Number per millimetre.	4	...
	Nature of walls	...	Thin.
Fibres	Length	...	1 200 to 1 500 µ.
	Average thickness of their walls.	...	4 to 6 µ.
	Maximum diameter	...	18 to 20 µ.
	Direction	...	Sinuous.
	Proportion per cent in the fibrous mass (F.)	70 °/₀	...
Woody parenchyma	Proportion per cent including medullary rays (P.)	20 °/₀.	
	Distribution.	Around the cells	
Cellular contents.	Oxalate of lime	In prisms ± cut in the woody parenchyma.	
	Starch	Quite abundant in the parenchyma and medullary rays.	

Secretion system differentiated.
...
Tanniferous, gummy, resinous or colouring matter.
Colouring and tanniferous matter in the medullary rays and parenchyma.
Seasonal layers.
Sometimes quite visible.

Bark	External characteristics. Greyish cork.
	Cortical parenchyma. Fairly thick with sclerous particles.
	Pericyclic region. Exfoliated in old bark, fibrous ring in young bark.
	Liber (inner bark). Stratified with bands of sclerous cells and fibres.
	Secretion apparatus. Secretion cells and mucilaginous cells.

ducts (production of charcoal, tar, paper-pulp);

8. To reduce shipping and rail charges and to facilitate the grouping of consignments in order to reduce the cost of transport.

It is particularly necessary that the steamship companies should realise that railway sleepers are an exceptional class of freight, easy to handle and to stow aboard ship, giving a full cargo with a minimum of inconvenience. It is therefore, in the interests of the companies to aid the development of this traffic by granting it reduced tariffs, instead of, as at present, applying a uniform rate which takes no account of the difference in value between common wood, such as that used for sleepers, and the expensive woods used for furniture. The latter varieties, in view of their high selling prices, can stand high freight charges which cannot be borne by the common varieties.

It may be said in conclusion that after the difficulties and disappointments inseparable from all innovations, the use of sleepers made of colonial timber is beginning to spread in France, where it will be found both economical and convenient.

A. C.

[625 .236 (.73)]

Cleaning passenger car equipment, [1]

By F. W. STEVENS,
GENERAL CAR FOREMAN, MISSOURI-KANSAS TEXAS, SAN ANTONIO, TEXAS.

(From the *Railway Mechanical Engineer*.)

One very important item in connection with the operation of passenger trains is to have all cars in presentable condition, both inside and outside. This importance is increasing daily due to the demands of the traveling public, which is brought about, possibly, by the public being more fastidious, and the severe inroads the buses have made on the passenger traffic of railroads.

Since the proposition of keeping cars in presentable condition is a duty of the car department, it behooves us, the carmen, to put forth every effort to attain this end most economically. Proper survey should be made of all points where passenger cars are cleaned, and the condition fully studied, in order to bring about the desired result.

It is possible that many of us have looked upon the cleaning of passenger cars as a necessary evil and have been prone to follow, in many cases, the lines of least resistance.

The first and foremost requirement in connection with the proper cleaning and caring for passenger equipment is a properly organized group of well trained men, working as a unit, carefully supervised; because where human element is involved, in many undertakings, its efficiency will only be as great and enthusiastic as that of its leader. Consequently, great care should be taken in

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[1] Paper read before Southwest Master Car Builders' and Supervisors' Association.

selecting a supervisor to handle men who are engaged in this sort of work.

Two classes of passenger car cleaning.

Passenger car cleaning on the whole can be easily divided into two general classes: first, terminal cleaning; second, heavy cleaning.

By terminal cleaning, I mean that cleaning which is given to every passenger car at the end of its trip. By heavy cleaning, I mean periodical scrubbing and renovating. These two classes of cleaning should be carried on as distinct and separate operations by groups of men working as separate units assigned to each.

The cost of cleaning will be governed a great deal, by the track layout available for such purposes. All coach cleaning tracks should be furnished with water, steam and compressed air, and should be well drained. In addition to the track layout and facilities, the men should be supplied with the proper tools to do this work, and all material should be placed in a convenient place centrally located to all tracks.

The first operation of terminal cleaning, or the cleaning that is given to every car at the end of its run, should be made by the man who is assigned to blow out cars, or use the vacuum. This man should first go through the car and raise all the windows, pick up all newspaper, fruit peeling, etc. He should start this cleaning on the vestibule of the car, being careful to clean around all of the vestibule trap doors, brake shaft and steam heat handles, as these places always catch more or less dirt, and if this is allowed to pile up, it will make an unsightly appearance. He should then go inside of the car, cleaning it for its full length, cleaning the seat cushions and backs, as well as the curtains, etc., as he goes along.

This man should be followed by the cuspidor cleaner. All of the cuspidors should be removed from the car and taken to a building assigned for that purpose, and thoroughly cleansed with hot water. A small amount of some standard disinfectant should then be put in them. After all other cleaning operations have been performed the cuspidors should be returned to the car.

This latter man should be followed by the floor sweeper, whose duty it is to sweep the floor clean of all dust and dirt, using for this purpose a counter brush, so that he can get around all the seat castings, steam pipes and other fixtures that he could not ordinarily get around by using the regular floor broom. This man should also be equipped with a putty knife or scraper, so he can clean out all corners and around seat castings, and remove from the floor that pest of all car cleaners, chewing gum.

Working with the sweeper, there should be a man to clean out the toilet rooms and hoppers. This cleaning should be done with plenty of soap and water, to which has been added a little disinfectant.

This man should be followed by two men, one on each side of the car, whose duty it is to wipe down with rags lightly saturated in renovating oil, the entire inside finish of the car, cleaning the windows on the inside at the same time closing them and adjusting the shades on an even line about 8 inches above the window sill.

The next man through the car, provided with a bucket of soap suds and a short broom, should scrub the floor, seat castings and steam pipes thoroughly, to be sure to get the dirt off the steam pipes, and steam pipe hoods. If there is any place in a passenger car where dirt will show up easily, it is on steam pipes and hoods, and during the winter time while steam is on in the cars, bad odors are very apt to arise.

The floor should then be mopped carefully by a man with a mop and a bucket of clear water, to which has been added a small per cent of disinfectant. No

more than three or four square feet of floor space should be cleaned without rinsing the mop. A dirty mop will do more toward making an otherwise clean car have an unsightly appearance than anything I know of.

This should complete the interior cleaning of the car.

Outside cleaning

Working with the inside men, as listed above, should be four men on the outside, whose duty it is to wipe down the outside of the car, and clean all window glasses. These men should work from ladders built for that purpose, and during fair weather should be equipped with dry rags, some kind of good glass polish, a window stick and a putty knife which should be used in cleaning the corners of the window glass. I wish to add here that this is the most important part of cleaning the windows, for if allowed to go without scraping with a putty knife, or some other tool, the dirt will collect until the windows have a very unsightly appearance at the corners. For wiping the outside of the car, they should have dry waste lightly saturated with renovating oil, and tightly wrapped with string, in a flat shape; the renovating oil should be put on the waste and then beaten with a heavy piece of wood in order to distribute the oil evenly and prevent streaking the sides of the car.

During bad or rainy weather, the outside cleaning will of course, have to be done by washing down the outside of cars with brushes and clear water.

This should conclude the work of terminal cleaning of passenger carrying cars.

The floors of all baggage cars and mail cars should be thoroughly cleaned and washed and properly aired. This work can be taken care of with regular assignment as listed above. For instance, the man who cleans out the toilet rooms and hoppers will not have enough to do to take up all his time, consequently he can be assigned to washing out all baggage cars. The man who blows out, or vacuum cleans passenger car interiors will have ample time to wash off all of the trucks and the floor sweeper should have sufficient time to sweep off all vestibule platforms.

Heavy cleaning every 60 days.

You will notice I have specified a period of 60 days. The length of time between heavy cleanings will depend primarily upon the condition of the weather during that period. I feel that every coach and baggage car should be thoroughly scrubbed every 60 days, both inside and outside. The outside scrubbing may be done by using either soft soap, or by using a prepared solution of oxalic acid and common table syrup, mixed in water to 15 % volume. The outside work should be assigned to two men, working from trestles six feet high and twelve feet long made of light material so that they can be moved easily.

The scrubbing should be done with a short handle brush (old wash down brushes may be used for this purpose very economically). In scrubbing the exterior of the car a space of approximately six square feet should be scrubbed at a time, and then be washed off with clear water, allowing none of the soap or the acid mixture to remain on the surface. After the entire exterior of the car has been scrubbed in this manner, it should then be rubbed down with waste saturated in renovating oil and followed by wiping down with dry waste, until the entire surface is dry.

The inside scrubbing or cleaning of the headlining, should be done by two men working from short trestles, using soft soap applied with regular painters' scrub brushes, and then washed off with a sponge. The headlining should then be wiped dry with either chamois skins or soft rags.

The car that receives heavy cleaning should also go through the interior ter-

minal cleaning process as outlined above.

We must not overlook the trucks in our heavy cleaning. They should be washed off, cleaned with an acid mixture in order to remove all dust and grime, and after they have thoroughly dried, all exposed parts should be painted. It is also good practice, especially when the car is over-due for shops, to touch up the exposed portion of underframes with quick drying paint.

Much can be done toward improving the interior appearance of a passenger car by keeping the floors and seat castings, as well as steam pipes, painted.

I have made no mention of the cleaning of dining and business, or special cars, as this is a special work and it would make my paper too lengthy to properly describe a method that should be used in these cases.

The cleaning plan as outlined above, and the number of men given, is for a force capable of taking care of the cleaning of from 36 to 40 cars per day, which should be handled at a cost of approximately $1.40 per car, average for labor and material.

[656 .215 (.73)]

The lighting of railroad yards, [1]

By H. E. MAHAN and R. J. SWACKHAMER,

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Figs. 1 to 4, pp. 494 and 495.

(*Railway Age.*)

Freight terminal yards are classified in accordance with the purpose that they are intended to serve, such as receiving yard, classification yard, departure yard, etc. A classification yard should be provided with sufficient light on the cars to permit safe walking on the tops, along the tracks to clearly see the switches and between cars to permit safe walking in these areas. Dark shadows handicapping the policing of the yard should be avoided and glare, the bugaboo of all kinds of lighting, should be carefully guarded against.

In the case of the retarder system the operator must clearly see the « cuts » as they move over the ladder; changing shadows that will disconcert him as to the speed at which the « cut » is moving must be avoided. A higher intensity and a more diffus illumination should be provided at the throat of the yard in the retarder system as it is here that the cars are retarded to drift to their destination; whereas, in the case of the car rider system, control of the cut is maintained until it is coupled to the train being made up. The operator controlling a retarder yard must clearly see the cars to judge and regulate their speed; he must be able to see the intervening track between the cut and the train it is to join in order to impart to it the speed it must have to reach its train and couple without damage.

The above lighting requirements must

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(1) Abstract of a paper presented before the twenty first-annual convention of the Illuminating Engineering Society, Chicago, Ill., 11-14 October, 1927.

be satisfied with due consideration to the limited space in railroad yard for placing poles or towers and with the least cost of installation and maintenance for the maximum of efficiency. The light source found most satisfactory in fulfilling these conditions is the so-called floodlight.

Economy of installation and operation are favored by concentrating the power requirements in light sources of large capacity at a few locations throughout the yard; minimizing of shadows and uniformity of illumination are best effected by using a large number of smaller units spaced at short intervals in the yard. A compromise of these factors has resulted in the practice of using floodlighting projectors with light sources of 1 000 watts capacity grouped in batteries of from 3 to 12 units as best meet local conditions. Owing to the prevalence of dust, dirt and corrosive gases in a railroad yard and exposure to the elements, a floodlighting projector in this service should be weatherproof, dust proof and non-corrosive. The necessity of working on a tower in maintaining the equipment requires that the operations of relamping, cleaning, focusing and adjusting may be done conveniently and safely by the workmen. As most of this work will be done in the daytime, it is desirable that it can be done without disturbing the positioning of the projectors or that the projector may be returned to its original position by mechanical means, otherwise it will be necessary to visit the tower again after dark to adjust the direction of the beams. As the wind stress is the most important factor in the determination of the size of the tower members, the projectors should offer as small a windage area as possible and their weight should be kept to a minimum for convenience in handling. Convenient focusing and adjusting mechanisms must be provided.

The cost of towers, distribution system, etc., tends to make the cost of producing a unit of light high and warrants the use of reflectors of the highest coefficient of reflection and their careful upkeep.

Methods of lighting.

The lighting of a railroad yard is largely a matter of adapting principles found best by experiment and experience to the conditions peculiar to the yard in question. There are for the most part two general systems of lighting; namely, group and distributed. By the group system is meant an arrangement whereby the projector equipments are concentrated at relatively few points. The distributed system, on the other hand, employs a number of locations with the projectors distributed throughout the yards.

Both of the systems are further subdivided, depending upon whether the light is projected in the direction of traffic or against the direction of traffic. A distinct difference in visual effect results from the two arrangements. Light projected in the direction of traffic eliminates to a great extent the possibility of dangerous glare and makes objects visible by reflected light. On the other hand, with the light delivered against the traffic, objects are seen in silhouette against a bright background and the specular reflections from the rails clearly define the tracks. It is obvious then that a compromise is desirable. Just such a compromise has been found to work out very satisfactorily in practice. Since objects near are seen perhaps to the best advantage by direct or reflected light and those at a distance by silhouetting them against a bright background or against the specular reflections from the rails, it has been found that a ratio of approximately three to one in favor of « with traffic » projection of light works to the best advantage.

It should be borne in mind that in the foregoing discussion we are considering

gravity switching classification yards. As stated previously, the selection of a system of lighting depends to a great extent on local conditions. Adequate room for tower foundations, source of power and many other conditions of a local nature must of necessity have a bearing on the solution. Further as an aid in determining the system to be used, a careful analysis of the comparative costs both initial and operating of the two systems as applied to the yard in question will prove of interest and at the same time more than likely be the deciding factor. The distributed system obviously costs more to install and maintain but at the same time it provides a uniformity of illumination together with an effectiveness in fog and smoke that is sometimes very difficult to obtain with other means of lighting.

Receiving and departure yards in general are taken care of in quite a similar manner to gravity classification yards. « Flat » or engine classification yards in the majority of cases can be handled to advantage in a different way. Inasmuch as this type of switching means two-way traffic, it is good practice to employ the group system with two-way projection of light. This means of lighting is invariably found to be the most economical and at the same time entirely satisfactory.

Mechanical retarding of cars and the areas that go to make up the active part of a yard employing this method of control bring into this discussion still an entirely different scheme of lighting. This means of retarding is comparatively new and to date very few yards have been illuminated. Experience, limited as it is, however, indicates that it is essential that the projector equipment be located in such a way as to project light in the same direction as the operator views the various movements. This means usually from three to six locations, depending on the size of the yard and the number of control points. Inasmuch as towers are required in such a yard to enable the operator to occupy a point of vantage, an opportunity presents itself to combine the retarder control and floodlighting towers in a single unit. This, however, to the knowledge of the authors, has not been done and prevailing practice is to mount floodlighting towers a short distance behind the control towers.

The 1926 report of the committee on illumination of the Association of Railway Electrical Engineers recommends lighting intensities of 0.04 to 0.15 lumens per square foot for ordinary requirements and suggests considerably higher values where speed of operation is of prime importance.

It is the opinion of the authors that values ranging from 0.25 to 0.50 lumens per square foot should form the basis of design for average intensities over the active areas of retarder yard. Of particular importance in this type of yard is the question of adequate coverage and, consequently, when this feature has been carefully planned the illumination values invariably run in excess of those mentioned above.

This brings us to an important point in the design of railroad yard lighting irrespective of the proposed system — that of coverage. Inadequate coverage is frequently characterized by objectionable glare. In other words, uneven illumination creates contrast and dangerous glare results. The remedy for this condition is the use of projectors with the proper beam characteristics. High mounting heights, of course, tend to eliminate glare and produce uniform illumination and by supplementing this with projectors of suitable beam characteristics we can be sure of illumination free from objectionable glare and in every respect satisfactory.

Towers and their locations.

The practice of grouping a number of large capacity units at comparatively

Fig. 1. — A lighted retarder yard showing control towers and a retarder.

Fig. 2. — An example of silhouette lighting.

Fig. 3. — A yard illuminated by the « group » system of lighting, illustrating vision by reflected light.

Fig. 4. — A railroad yard illuminated by the « distributed » system of lighting.

few locations has brought about the use of towers ranging from 75 to 115 feet in height. Naturally, towers of these proportions require substantial foundations and unfortunately in some of the older yards difficulty is encountered in finding the necessary space. When such a problem presents itself the answer must obviously again be a compromise. It is desirable, of course, to make use of any natural elevations that exist and in car rider yards it is considered good practice to locate a lighting tower, which may be called the master tower, on the high point of the hump. Frequently, due to limited space at the hump it is necessary to place a tower at a lower level, in which case additional height is provided and the structure located as near as possible to the hump. Suitable space for towers can generally be found for the remainder of the yard either in the body of the yard or along the sides. The best results will be had by projecting the light parallel with the tracks.

The maximum effective range of light projection depends almost entirely on the smoke and fog conditions encountered. Our experience would lead us to believe that approximately 2 000 feet represents a practical maximum. The range of a projector is in a sense unlimited, but the effectiveness of the light projected must necessarily depend on prevailing conditions. This, then, means that tower spacings range between approximately 2 000 and 4 000 feet depending upon the system employed. The average yard under these conditions will require about four towers with, approximately twenty projectors. The initial installation and foundation costs of the tower, therefore, represent the greatest item of expense in a yard lighting system and make necessary careful consideration in the selection of tower locations.

As stated, towers for railroad yard use range from 75 to 115 feet. Ninety-foot structures have found favor with many railroad systems. This height is in keeping with present day practice and represents a practical compromise. Difficulty is quite often experienced in raising assembled towers that exceed 115 feet in height. The majority of cranes found in railroad service will swing 90-foot-110-foot structures with ease.

Fabricated steel is quite generally accepted as standard construction for towers, this being brought about largely because of the suitability of this construction for the heights demanded and the permanent nature of such a structure. Baskets or platforms are arranged on these towers to accommodate the number of projectors required and good practice provides for reasonable expansion by allowing for additional projectors. The projectors are arranged in two tiers and located as near as possible to the outer edges of the platform in order not to have the light intercepted by the platforms.

In the interests of the safety of the men working on these towers, a ladder mounted on the inside of the tower is provided as a means of reaching the platform. This ladder runs from the ground to the platform where a trap door is provided, which when closed is flush with the floor of the platform and forms a part of it. Such provisions as rest platforms, half way between the ground and the top, have proved satisfactory.

Power distribution and control.

There is, as a rule, power available at or near a railroad yard. This power ranges from 2 300 to 6 000 volts and is used, when stepped down, for various purposes in and around the yards and shops. The addition of a lighting system means in some cases an extension of the present service while in other instances entirely new lines or circuits have to be run. In the former, the practice is to bring the high tension to each of the tower locations where it is stepped down and controlled, each tower as a

unit. Where new lines are run and particularly where they serve the lighting only, an opportunity is given to control the entire lighting service at the power station. There are in general the following methods of control :

1. Each tower : controlled separately on secondary side.
2. Complete installation : control of primary by master switch at station.
3. Cascade : relay and contactor arrangement turning towers on successively.
4. Carrier current : controlling the entire system.

Design and maintenance.

There are many factors requiring consideration in the design of a railroad yard lighting system and many of the means of satisfying the requirements demanded by these factors are in conflict with each other, necessitating a compromise in the final design. This makes necessary a careful study of the conditions and requirements surrounding each yard in order that these factors may be intelligently weighted and the compromises made in a practical manner. In the case of new yards the efficiency of the lighting system may be greatly enhanced by making provisions in the layout of the yard for suitable tower locations.

The matter of proper maintenance is also essential. A well designed system of lighting may soon deteriorate into one very unsatisfactory if the equipment is not systematically serviced. Dust and dirt absorb light and burned out lamps, affect the distribution of light throughout the yard and lower the level of illumination.

The railroads approached this subject with some trepidation, fearing that by illuminating the yards there would be difficulty in seeing the switch signals. Experience has proved this to be unfounded, the colored lights of the signals appearing as clearly in contrast with the yard lighted as they do with the yard dark. Statistics compiled by the railroads clearly demonstrate the economic advantages of the lighted yard as against the unlighted yard.

[656 .212.5 (.73)]

Comprehensive reports speed yard operations at Selkirk.

Figs. 1 and 2, p. 500 to 502.

(From the *Railway Age.*)

The average terminal time per car eastbound has been reduced, in one year, from 10 h. 3 m. to 6 h. 27 m., at the gravity yard of the New York Central at Selkirk, N. Y. This has been accomplished by continuous and comprehensive analysis of efficiency and cost statistics, which are prepared currently and analyzed by the trainmaster and general yardmaster daily. These cover all of the yard activities in detail and are prepared in such a manner as to enable the supervisory force to determine at once where the responsibility lies for any delay to a car or group of cars.

The terminal time on the westbound movement has shown a slight increase, but this is due entirely to the fact that,

in 1927, car retarders were in the course of installation in the westbound classification yard and operations were hampered during the construction period, as the contractors were working on 25 % of the track at one time. Despite this temporary handicap, however, the average terminal time westbound was only 14 h. 47 m. during the period of a month, while the grade of the hump was being changed and other construction activities were in progress.

A typical fast freight movement.

Most of the perishable and other fast freight moving eastbound through Selkirk is not put over the hump, the trains having been pre-classified at De Witt yard, the next terminal point west of Selkirk. The work done at Selkirk consists of inspecting the trains in the regular manner, also inspecting all cars of perishables to ascertain the condition of their ventilation and refrigeration, icing such cars as require it, and a certain amount of cutting out and filling in of cars.

A typical movement of such a train was observed on 25 September 1927. The train arrived at Selkirk at 11.30 p. m., with 84 cars, 3 273 tons. It was necessary to inspect 24 cars of perishables, 6 of which were found to need icing. Icing was started at 11.35 p. m. The car inspectors started on the train at 11.55 p. m., at which time the last spot of the train was made for icing, and completed their inspection at 12.15 a. m. In the meantime, nine cars were set off the head end and the two rear cars were switched out, while a carload of automobiles was added. The outbound engine was placed on the train at 12.15 a. m. and the train left the yard at 12.25 a. m., or an elapsed time of 55 m. between arrival and departure.

The movement of bad order cars through the yards is also checked in detail. During a typical 31-day period, 25 August, to 24 September 1927, 908 eastbound loaded bad order cars were repaired at Selkirk, with an average terminal delay of 20 h. and 10 m. per car. During the same period, 222 westbound cars were repaired, with an average terminal delay of 23 h. and 43 m. per car. An example of what can be done in cases of necessity was observed at Selkirk when the car repair forces changed a pair of wheels under a refrigerator car, and it was sent out in the same train in which it arrived, the car and the train in which it was having been in Selkirk yard just 45 minutes.

Selkirk yard is situated about eight miles south of Albany on the Castleton cut-off of the New York Central. This cut-off was built to avoid the necessity of handling freight through Albany proper and it is used for freight traffic exclusively. The construction of this cut-off has had the result of greatly reducing the terminal delay on all cars. As a result of the efficiently supervised operation at Selkirk, this time saving has been steadily increased, until now from 8 to 26 hours are saved on every car moving over the cut-off and through Selkirk yard, as compared with the prior movement through Albany.

Traffic through Selkirk.

The business handled at Selkirk averages over 4 000 cars a day. Eastbound business is delivered from the New York Central proper and from the West Shore, these two lines being practically parallel from Buffalo to Albany. Westbound business is received from the New York Central proper, which runs along the east bank of the Hudson river from New York to Albany, from the West Shore, which runs along the west bank of the Hudson from Weehawken, N. J., to Albany, and from the Boston & Albany, which serves central Massachusetts and Boston. Westbound cars from the New York Central and the Boston & Albany are brought

into Selkirk over the Castleton cut-off, which crosses the Hudson on the A. H. Smith Memorial Bridge, while westbound cars from the West Shore River division are delivered at a junction point at the east end of the yard. The same movement, in the reverse direction is followed on east-bound cars outbound for the New York Central, Boston & Albany and West Shore, while westbound cars move out over both the New York Central and the West Shore for Buffalo, intermediate stations and points beyond. The preponderant loaded movement is invariably eastbound.

The yard layout is shown in the accompanying diagram (fig. 1), from which it will be observed that straight-line operation is carried out on all movements through the yard. A summary of the trackage and capacity of the various component yards is given below:

Yard.	Number of tracks.	Car capacity.
Westbound receiving	15	1 045
— classification	24	1 857
— re-classification	8	160
— departure	13	1 464
Eastbound receiving	8	968
— fast freight	5	419
— classification	21	1 647
— re-classification	7	109
— departure	15	1 014
Car repair	11	308

The yard is also equipped with modern and complete mechanical facilities, including a car repair shop and an engine terminal consisting of two engine-houses, one with 32 stalls and the other with 30, a power house, a coaling plant and a sanding plant. A well-equipped ice-house is also maintained in connection with the yard.

The power assignment

The yard is operated in three shifts, with 44 engine jobs. The following is the regular engine assignment for each trick :

Assignment	7.00 a. m.	3.00 p. m.	11.00 p. m.
Eastbound hump	0	1	2
— classification yard	4	5	5
— departure yard	2	2	2
Westbound hump	2	2	2
— classification yard	1	1	1
— departure yard	3	3	3
Engine house	1	0	0
Car repair yard	1	1	0

While this is the regular power assignment, it is controlled, of course, by the necessities of the traffic moving. Frequently, at the end of the week it is necessary to call out additional locomotives to shove cars over the westbound hump, also to pull cars from the classification yard. Similarly, it is necessary frequently to follow the same procedure in the eastbound yards during the early part of the week.

This assignment was planned so as to permit the working of the locomotives continuously through two shifts, so far

as the jobs permit. Ordinarily, the crews change on the ground. When an engine has been in service in the yard for 16 hours, it is run to the engine house by the crew, who take out another engine that has just received engine-house attention. Of course, this « endless chain » operation cannot be carried out on the engine house job or the car repair yard job, where locomotives are not used on all three shifts, nor can it be used on the extra engine jobs. However, the increased power utilization made possible by this means is such that all of the regular 44 jobs and the extra jobs are now being protected adequately with only 25 yard engines.

All of these locomotives are of the « U » type, with the exception of four Mallets used in humping service and a trimmer engine of the « B-10 » type. The « U » type locomotives have eight drivers, the weight on drivers being 219 000 lb.; the « B-10 » type six drivers, and the weight on drivers 158 000 lb.; three of the Mallets have sixteen drivers, with a weight on drivers 466 000 lb.; while one Mallet has twelve drivers, and a weight on drivers 363 000 lb.

An interesting experiment is being conducted as to the uses of radio in a hump yard. Radio sending and receiving sets have been installed in the cab of one of the humping locomotives and in the hump yardmaster's office, so that verbal communication is established and the humping operation may be conducted without the aid of signalling. The installation has not yet been in service a sufficient length of time to enable final judgment to be passed on it, but the results so far have been satisfactory.

All yard movements controlled.

The facilities at Selkirk are unusually large and widespread, as may be gathered from the summary of capacity previously given. Even in a relatively small yard, time wastes and leakages and lack of co-operation in engine movements are quite likely to occur and in a yard of this size the chances are, of course, much magnified. With all the involved locomotive manœuvers necessary in the operation of the yard, it was felt that, to secure the maximum efficiency, the control of all movements throughout the yard should be delegated to some one person. Accordingly, three director yardmasters were appointed, one for each shift, and every movement within the yard limits is under their direct control. This new departure in yard operation has proved highly successful at Selkirk.

In effect, these director yardmasters serve as dispatchers for the yard. They have before them a form, shown in the accompanying illustration (fig. 2), that

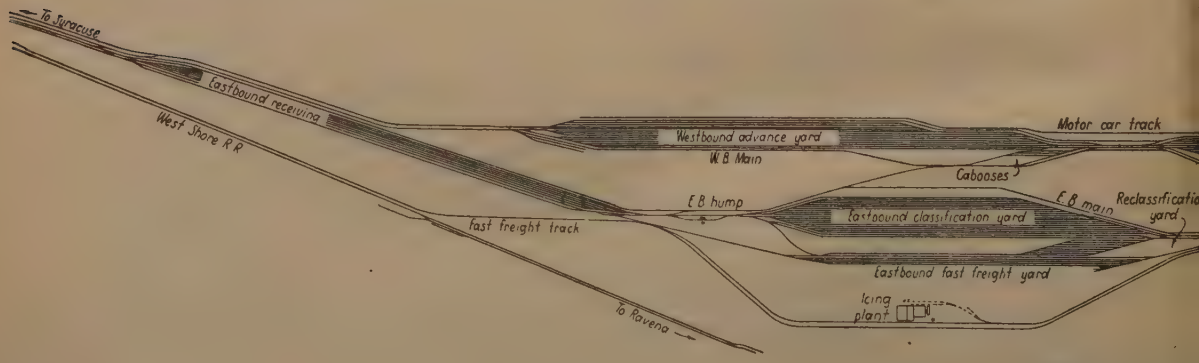


Fig. 1. — Diagram showing t

corresponds to a dispatcher's train sheet, adapted to the needs of yard operation instead of road movements, and they are in constant communication by telephone with all parts of the yard. Space is provided on this sheet for the entry of all information necessary for the control of yard movements. All changes in the yard situation are entered currently throughout each director yardmaster's tour of duty, so that any officer may come to Selkirk at any time and, by a glance at the worksheet, be apprised of the exact situation existing at that time.

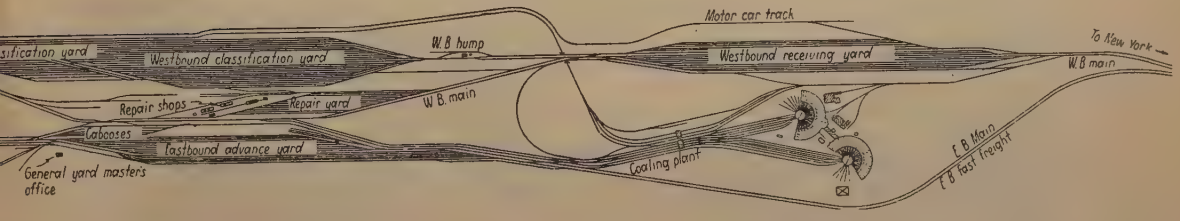
The director yardmaster is charged with the responsibility of calling all yard crews and also road crews for trains leaving the yard. In addition to the regular records maintained in connection with the calling of the road crews for outbound trains, a yard crew calling sheet is kept, which gives the names of the men assigned to the various jobs each day, divided into groups corresponding with the various sections of the yard. This sheet shows where every man is working at all times, as well as the number of extra men not working on regular jobs, who are, however, available for call.

Another important duty of the director yardmaster is to control the « endless chain » system of yard engine utilization previously described. The director yardmasters carry on their sheet a record of the time when each locomotive is due for engine-house attention and issue orders to the crews accordingly. To aid the director yardmasters in determining the assignment of power and crews in advance, consists giving the complete make-up of trains enroute to Selkirk are telegraphed from the other yards in advance.

Yard situation reports.

A comprehensive system of daily yard situation reports is prepared by the director yardmasters and the yardsmasters in charge of the various yards. These reports enable the trainmaster and general yardmaster in charge of Selkirk to know the situation currently and determine at once where the responsibility lies for any delays. The general yard situation report is prepared every eight hours and is on the desks of the trainmaster and the general yardmaster immediately after the conclusion of each trick. It shows in detail just how many cars are in each track throughout the yard and to what points these cars are destined.

Separate situation reports are prepared for both the eastbound and westbound classification yards, which are sent to the office at the close of each 24-hour period. These reports are divided into sections so as to show the detailed activites of each trick separately. If a yardmaster is not clearing the tracks



ting layout at Selkirk Yard.

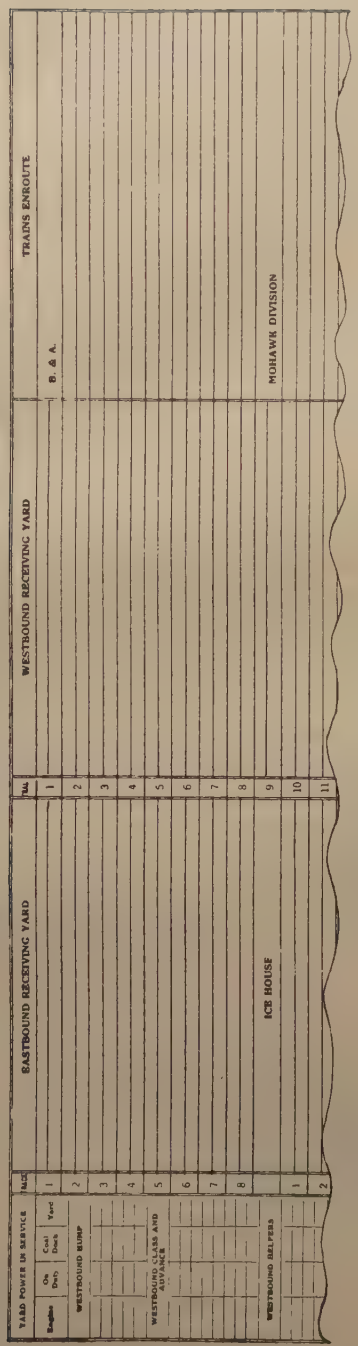


Fig. 2. — The form used by director yardmaster in controlling yard movements.

and moving the cars promptly, this situation is reflected immediately on these reports. For example, a car may be humped prior to midnight. If it has not left the classification yard by the end of the trick, or 8 a. m., the yardmaster in charge of that trick is asked to explain why, as it is a rule at Selkirk that classification tracks must be cleared at least once every eight hours, while a number of these tracks are cleared every two hours.

The rendering of these reports, with the resulting increased opportunity for detailed supervision, has had much to do with the increased efficiency of operation at Selkirk. The yardmasters in charge of the various operations know that any failure on their part is immediately apparent and the responsibility clearly fixed at once. Conversely, they know that any good work on their part is also refected in the reports immediately. Thus they have additional incentives for doing the best work possible under all conditions. Supervision is materially facilitated since both the general and the detailed situations are reflected at frequent intervals, and if a delay occurs to any one car or group of cars, the responsibility may be fixed at once, without having to make an extended investigation.

Terminal delays reduced.

The director yardmaster in charge of each shift renders a report on delays encountered during his tour of duty in getting trains out of Selkirk. This report shows eastbound and westbound trains separately as to divisions and gives the number of trains, total delay and the average delay per train. For the week ending 2 October, the average delay per train was 7 minutes westbound and 8 minutes eastbound.

This remarkable showing is attributable to two causes : First, the placing of the entire responsibility in the hands of the director yardmasters, and second, enabling a check to be made of relative per-

formance by means of this report. The director yardmasters, of course, are familiar with their relative daily performances, but this is carried further by posting notices where all the employees may see them, showing the relative performances of each shift in this regard. By this means a spirit of healthy rivalry has grown up between the shifts and a more concerted effort is made by the men and their supervisors to avoid such delays.

The fast freight movement.

Normally, the eastbound manifest, or « 24-hour trains, fast freights » as they are known on the New York Central do not pass over the hump. These trains are practically all pre-classified at De Wit, as previously explained. The dispatchers west of Selkirk telegraph the consist of these trains and their probable arriving times to the director yardmaster at Selkirk, 2 h. 30 m. before the trains arrive. The director yardmaster then arranges for all necessary work that will have to be done upon arrival, estimates the time it will take, and calls an outbound road crew for a departure time based on this estimate. Since the director yardmaster knows the make-up of the train, he is able to line up the yardmasters on the ground as to what cars are to cut out and where the cut is to be made. The cars to be filled in are lined up, inspected and made ready to be grouped in the train as soon as it arrives in the yard.

As soon as the train arrives it is inspected and the cut-outs and fill-ins made. If, as is usually the case, it contains loaded refrigerator cars requiring icing, it is taken to the ice plant where refrigeration inspection and icing takes place. The road engine is attached immediately after the inspection is completed, taking sufficient time to test the air, after which the train leaves the yard on a thoroughfare track which does not conflict with other yard movements in the east end of the yard.

The scheduled yard time for fast freights at Selkirk is 1 h. 30 m., but this time is invariably bettered. In fact, a check of over two weeks indicates that the average yard time was approximately one hour.

An interesting example of high speed operation in connection with moving these fast freights through Selkirk is found in the handling of boxed automobiles loaded on flat cars. Some of the fast freights contain as many as 10 or 20 carloads of this class of traffic, many cars of which are too high to comply with the clearance limits east of Selkirk. The excess height is seldom more than two or three inches, and it has been found that by removing some of the wooden crosspieces and applying steel bands, the lading is just as well protected, and the cars then comply with the clearance limitations. A flat car is equipped with these bands and when the advance consist indicates that such cars are on an incoming train, the band car is lined up with an engine. As the train comes into the yard, the band car is run along an adjacent track, the wooden cross pieces are removed and the steel bands are applied, without switching the cars from the train or delaying the train at all. As many as 15 cars have been given such attention in one train, during the time the train was being inspected and iced, without any delay to the train.

These trains are never delayed for billing. As soon as they arrive, the bills are delivered to the yardmaster. He has ready all billing for cars to be filled in and he sorts out the bills for cars to be cut out. The conductor's report of the arriving train is used as a partial consist of the train departing, together with a consist of the cars filled in.

The car inspection forces are so distributed as to provide for the maximum flexibility in inspecting the fast freight trains. Normally, all inspection is done at the icehouse, but if three more trains are due close together, the first two trains are iced and pulled to the advance

yard for inspection, so as to get them out of the way before the third or fourth trains arrive at the icehouse. The icing is done under contract by an outside company and is unusually efficient, the average icing time per car is only 1 1/4 minutes.

The movement of manifest freight through the yard is covered by a fast freight report, rendered every 24 hours, which gives in detail the time required for each successive step in the operation of putting the train through the yard, divided as between eastbound and westbound trains. Like the other reports, it fixes the responsibility for all moves made by these trains through the yards and has been of material assistance in time studies and checking the movement of the fast freights to determine what operations were capable of being accelerated.

Daily cost statement made.

Assistance is rendered in controlling yard expenses at Selkirk by a daily estimate of yard pay-roll expenses, rendered in conjunction with a summary of the daily performance record of the yard. This report shows the number of cars handled daily, with the cumulative total for the month and gives a daily estimate of the daily pay-roll expense, divided to show the totals for the various classes of labor employed. It gives the cost per car handled, the yard engine hours and the cars handled per engine hour. Comparisons are given for all of these figures with those of the preceding month and of the same month for the preceding year.

This report enables the supervisors to make daily cost analyses and gives them far better control over their expenses than they would otherwise have, as any unnecessary engine jobs or excess car riders, in fact any unnecessary yard expense of whatever nature, shows up on the report the following day and may be remedied at once.

A check of the operations and cost, made on 25 September 1927, shows that 11.1 cars were handled per engine hour, as compared with 9.9 for the preceding month and 10.3 for the preceding year, while the cost per car was materially reduced. On the same day, the average terminal time per car eastbound was 6 h. 14 m., as compared with 10 h. 52 m. on the same day in 1926.

Bad order cars handled promptly.

The record previously mentioned of changing a pair of wheels under a car and getting it out on the same train it came in on, in 45 minutes, is, of course, unusually fast, but the forces at Selkirk make a specialty of repairing bad order cars and getting them through the yard in good time. The car shop and repair track facilities are modern and well equipped and a sufficient car force is maintained at all times. In addition, special stress is laid upon getting bad order cars on to the repair tracks as promptly as possible and removing them quickly after they are repaired. The general and detailled yard situation reports reflect the movement of bad orders as well as other cars through the yard. Supplementing these are the « cripple » reports, prepared by each yardmaster for the yard under his jurisdiction and a general bad order car report covering the entire yard.

A check made of the handling of loaded bad order cars requiring all classes of repairs, during the 31-day period, from 25 August to 24 September 1927, developed some interesting performance records. A total of 908 eastbound loaded bad orders were repaired at Selkirk during this period, and the average time per car was 20 h. 10 m. This figure, and those following represent the total time the car was in the yard, not merely the time spent on the repair track. Westbound loaded bad orders totaled 222 during the same period, the average time being 23 h.

43 m. On 13 September, 23 eastbound « cripples » were handled in an average time of 15 h. 51 m., while on 24 September, 8 westbound cars averaged only 13 h. 40 m. each. The average time on eastbound cars on 12 days and on westbound cars on 8 days during this period was less than 20 hours. The best record for both eastbound and westbound loaded bad orders was made on 24 September, when 36 cars were handled in 605 h. 5 m. or an average of 16 h. 8 m. per car.

[621 .139 (.73), 625 .18 (.73) & 625 .27 (.73)]

Pennsylvania Railroad experiments with budget for purchases.

Figs 1 to 6, pp. 505 to 513.

(*Railway Age.*)

For the past two and one-half years, the Pennsylvania Railroad has been experimenting with a budget for purchases. Less money tied up in unapplied material and more stability in stores are the aims of the plan which is administered by the stores department. Monthly requirements of materials are developed from the operating expense budgets of the Company. All supplies, excepting fuel, ties and rail, and certain miscellaneous materials, are affected and there is a budget for each of 42 different classes of material. During the first 10 months of 1927, total purchases did not exceed the total budget allotments at any time and the average monthly variation from the allotment was only 7 %. The value of

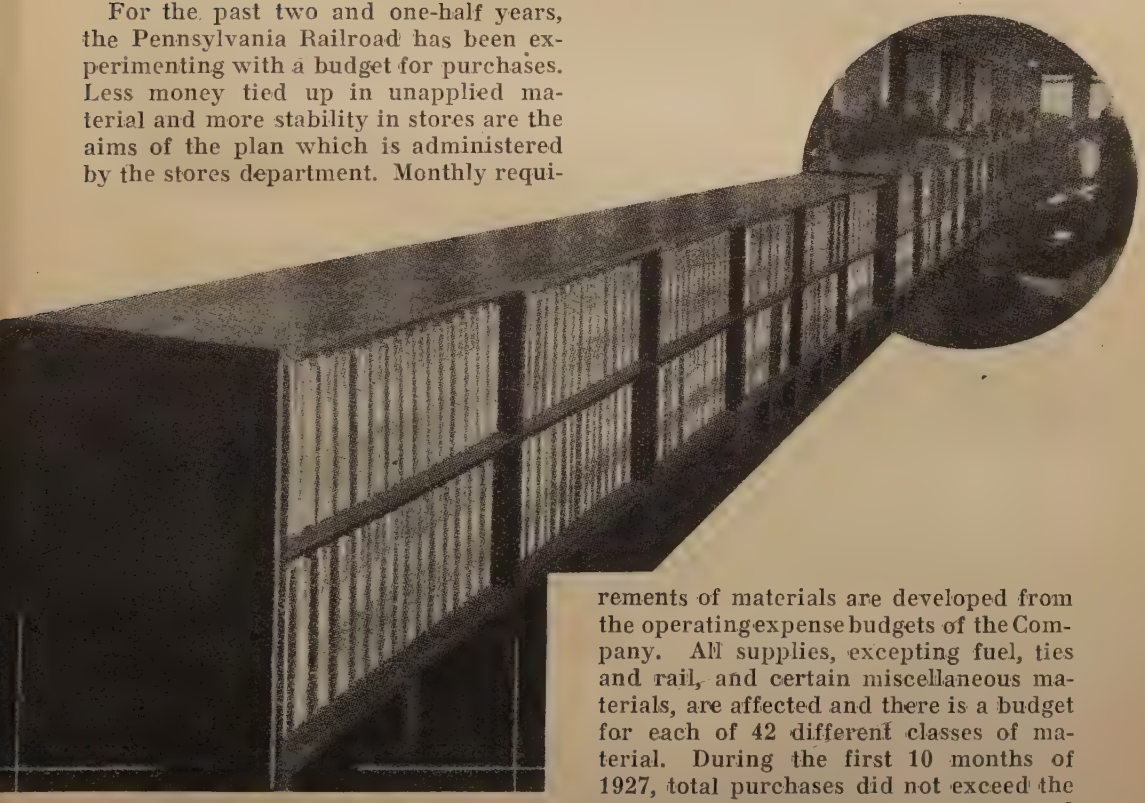


Fig. 1. — The master stock books of the Pennsylvania Railroad number over 300 volumes.

all materials and supplies on hand at present is within 8.5 % of annual operating expenses, and the stock of materials less fuel, ties and rail has an average turnover of 3.1 times a year.

Base budget on operating expenses.

The Pennsylvania's purchase budget is not widely understood. On or about the 25th day of each month, information of the expenses which the managements authorize for the operations of the railroad during the next month is obtained by the stores department. This operating budget separates the prescribed expenses for maintenance of equipment, maintenance of way and structures and transportation; but it does not distinguish between expenses for material and those for labor.

The supply department's only interest in this operating budget is for the information it will give as to the amount of materials which will be required under it. Since this information is not afforded directly, it must be developed indirectly. A formula is employed for this purpose in which the value of material is expressed as a certain fraction or percentage of operating expenses. This formula was developed from a study of the operating expenses and material consumption for more than three years. In such studies, the expenses have been limited to those for maintenance of equipment and maintenance of way, omitting transportation charges, while the value of materials consumed, which is represented by the issues to closed accounts, includes freight and inspection charges.

Find monthly operating need.

It was demonstrated that excepting for irregularities which can reasonably be foreseen the value of material used in the maintenance of equipment from month to month on the Pennsylvania is approximately 54 % of the expenses for maintenance of equipment, while the ratio of maintenance of way materials is approximately 51 % of the expenses in that department of work from month to month. The use of these ratios in connection with the operating expenses authorized for the month gives an approximate value for the material required during the month, which is called the operating need.

The next step is to determine the so-called operating need by *purchase*. The distinction lies in the fact that some of the material used is not purchased, but is reclaimed from scrap or manufactured on the property from raw materials, while the purchase budget is concerned only with materials which must be acquired from outside sources with the expenditure of money. The materials reclaimed and manufactured were found to comprise approximately 17 % of the operating expenses, which gives an average value for the materials required by purchase for maintenance of equipment of 37 % of the equipment expenses if the determination were handled that way. In practice, however, the ratio of 54 % is used directly and the actual current value of reclaimed and manufactured material as disclosed on the books, and being readily accessible, is then deducted to obtain the operating need by purchase. Thus if an operating budget authorized $12 000 000 to be spent for maintaining equipment in a typical month, the operating need by purchase for the required materials would be calculated as follows :

Operating expenses authorized	$12 000 000	
Total material required	54 %	$6 480 000
Less reclaimed and manufactured material		1 950 000
Balance to purchase maintenance of equipment (Operating need by purchase)		$4 530 000

A distinction is next made between the operating need by purchase and the *net* operating need by purchase. This is because the Pennsylvania's purchase budget is not designed to prevent the railroad from spending beyond a certain amount of money nor to place a limit necessarily upon the amount of material which users shall receive. The users must be supplied with their requirements. The object instead is to regulate the purchase of new material so that current requirements may be met without, at the same time, keeping any more material on hand than is essential to protect specific current needs. But the quantity of purchased material required for needs during the month may be more or less than the quantity of these materials which ought to be purchased during the month. If the volume of supplies already on hand, for instance, is greater than necessary, the actual purchases should be less than the requirements of purchased material for some of those requirements can be drawn from stock; otherwise, the excess stock will remain undiminished.

Unfilled orders considered

There may also be considerable quantities of material suited to the month's needs which, while not actually on the ground, have been ordered previously and will be received in due course if they are not already en route. It is a feature of the budget plan that this material is considered in the light of stock on hand. The explanation is found in the early period of this road's attack upon its unapplied material balance when the militant efforts to reduce the stocks by curtailing purchases were for a time defeated at every turn by a veritable flood of incoming materials covered by outstanding orders which stores officers, lacking summary reports, were temporarily at a complete loss to measure. The third step in the formation of the monthly purchase budget, therefore, is the reduction or enlargement of the operating needs by purchase sufficiently to arrive at the month's net operating needs by purchase.

Existing records of the stores and the purchasing departments contain the information for this purpose. The authorities have arrived at an ideal stock balance, which is called a normal stock, and the difference between the normal stock and the actual stock on hand is either a surplus or shortage. A record of the amount of material held for additions and betterments is also kept, and the separation of this from the excess gives a net excess of material on hand. This net excess and the value of outstanding commitments or obligations of the purchasing department give the net excess of purchased material available and the difference between this figure and the total operating need by purchase is the total net operating need by purchase. An example of the basic calculations is given as follows :

Operating needs by purchase		$4 530 000
System excess stock	$500 000	
A. F. E. and construction materiel	100 000	
Net excess	400 000	
Outstanding commitments	100 000	
Total excess available		500 000
Net operating need by purchase		$4 030 000

Past performance a guide.

This budget is broken down into small divisions for the best results. The number and kind of these divisions is a feature of the plan. There are 32 different classes of material for maintenance of equipment in this road's storekeeping

system and a total of 45 classes, not including ballast, rails, ties and fuel. An allotment is determined for each of these classes and each of these allotments is further divided into an allotment to cover the material required for general distribution and a separate allotment for material required for this company's manufacturing operations, which are largely centralized at Altoona.

The individual allotments are not determined simply by dividing up a predetermined total, however. The procedure is just the reverse. The individual allotments are determined first. This is partly because budget preparations must be well under way by the time the operating expense figures are available. It is also considered desirable to study the conditions affecting each class of material more closely than could otherwise be done. Thus past performance is relied upon first of all in preparing the individual allotments. This is reflected by existing records, giving the total stock on hand for each account and the stock held for additions and betterments, also the volume of purchases in previous months and the volume of outstanding orders for each of these classes. From these a value is used which represents a tentative net operating need by purchase for each of these classes of material, whereupon the total of these allotments gives a tentative net operating need by purchase or a tentative budget. This total is a check on the operating need by purchase as computed from the operating budget, while the latter figure in turn is a check on the tentative figure. If the tentative figures are high they are quickly reduced by employing as a guide to the reduction in each case a schedule giving the percentage which the average value of each class of material used in previous years bears to the average total consumption and also the percentage for manufacturing work. The budget is then ready for application.

One day to make budget.

The preparation of the Pennsylvania's purchase budget is not as prolonged as a description might indicate. The statistics of stocks on hand and of stocks reclaimed and used, for all of the classes of material considered, are obtained from the regulation documents which the accounting department of this road prepares for 11 different accounting areas embracing 19 reports each month and which the stores department abstracts in the form required for budget control during the course of the month. The record of material on hand for additions and betterment work is secured by operating divisions and this is also consolidated as a routine operation. This basic statistical work is carried on continuously during the month and would in large part be done if no budget were prepared.

The actual preparation of the purchase budget is done in less than a day. A work sheet is prepared in the general storekeeper's office which gives for each material account the value of excess material in stock for the system, the value of material held for additions and betterment work, the excess stock on hand for manufacturing, the average value of monthly purchases, the actual value of purchases for the same month of the previous year, the outstanding commitments for the previous month and the amount of material used on the system and in manufacturing work. From these values, which for brevity are reported only in thousands of dollars, the tentative budget for each class of material and for the system is quickly determined and recorded. This tentative figure is then revised in an hour's time when advance information of the operating expenses is received.

The schedule of allotments is issued on a single letter-size sheet which also gives the corresponding record of the orders placed in the previous month. As in all

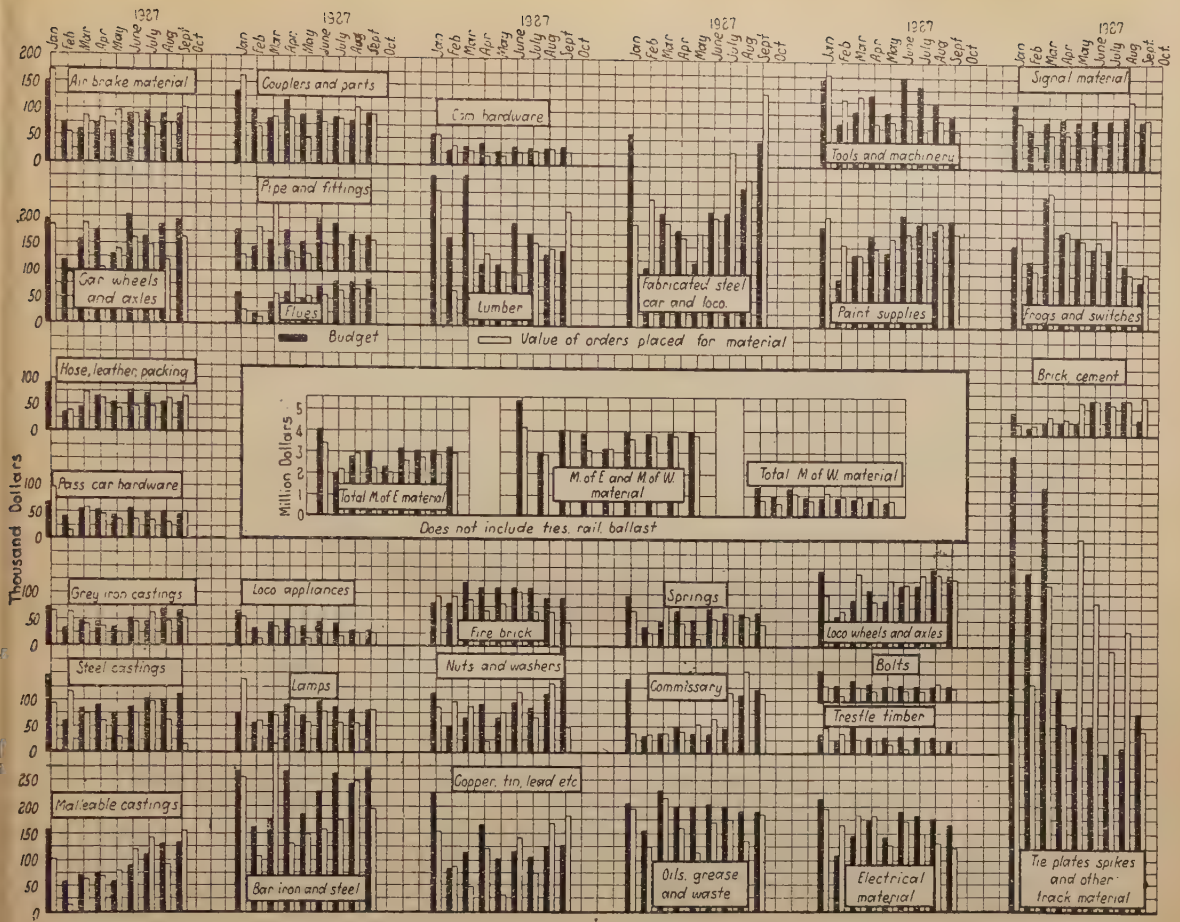


Fig. 2. — Chart showing purchase budget results during first ten months of 1927 for 34 groups of material. Black columns show expenditures authorized; white columns, expenditures made each month.

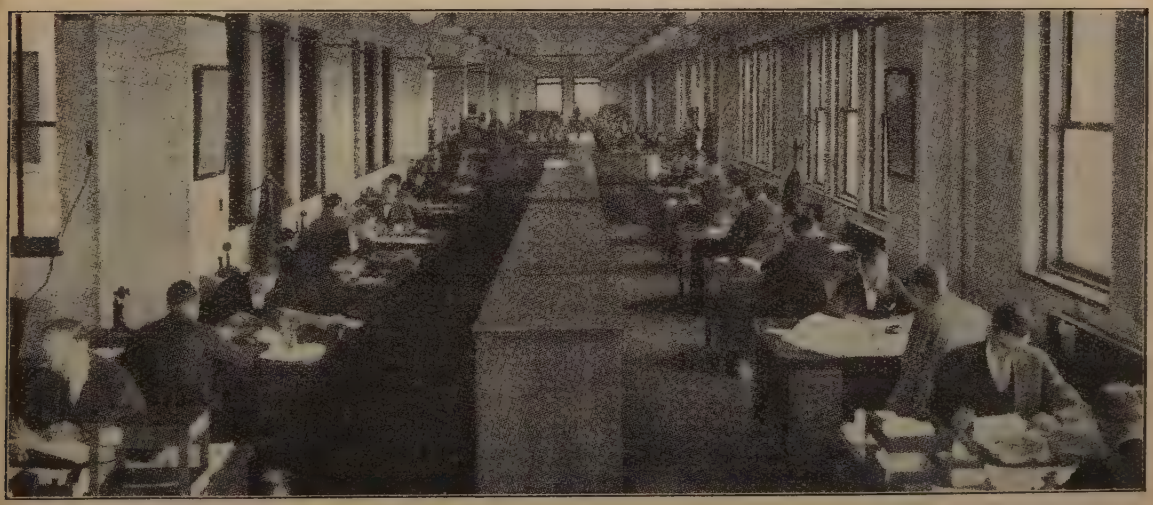


Fig. 2. — One wing of store Departement Headquarters as seen from the general storekeeper's office.

Master stock book cabinets in the center foreground with clerks checking books and drafting orders on each side. Purchasing department in background separated from store department only by railing.

preliminary calculations, the last three digits are omitted. Thus the figure 60 opposite Account I in the budget schedule for March 1927, signified that orders for April were to be kept within $60 000. The date of this budget was 3 March.

Check volume of orders daily.

The problem, after the budget has been determined, is to keep from exceeding it. The allotment for each account having been fixed, a running account is kept of it by means of a statement in which the allotment is apportioned equally among the working days in the month and the aggregate value up to the end of each day is recorded progressively. Columns are also provided for each day's purchase commitments and each day's accumulated commitments opposite these progressive allotments. Each month's statement for the system totals has one page for the separated reports of maintenance of equipment material for the system and for manufacturing organized in this manner, a second page for the separate reports of the total maintenance of equipment and maintenance of way purchases, and a third page for the grand total. The purchases are taken each day from the purchasing department books. This saves the stores department the expense of duplicating the work and it is a simple matter with the purchasing and stores offices on the same floor. These statements show the daily progress of purchases in their relation to authorized amounts so that steps can be taken to correct difficulties or meet contingencies which may develop during the course of the month.

Subordinate stores are neither called upon for assistance in preparing the Pennsylvania's purchase budget, nor do they become involved directly in its operation. When the size of the budget or the trend of the orders under the budget calls for a change in ordering policies at such points, this action is announced on a statement specifying the increase or reduction to be made in the average consumption for the past three months used by the storekeepers in preparing their stock needs for replenishment. This statement simply lists in one column the supply points affected, gives the symbol for the class of material to consider at each point in the second column and prescribes the present percentage of the reduction to be made at each point in the third and fourth columns. Its simplicity and directness is apparent at a glance.

Does not replace stock books.

The Pennsylvania has introduced the purchase budget with full knowledge of the skeptical view prevailing that the stock book, with the complete history of each and every item of material, is the instrument for controlling stock and (when supported by a proper organization and the conventional report of inventory) should be adequate to efficient control.

The Pennsylvania's answer to this is that the budget plan is not a substitute for these devices, but is an instrument for controlling, when business or other conditions require, the money involved in the purchase of supplies by subjecting the general storekeeper to a check before he may take final action. Attention is directed to the reorganization which has taken place in this road's supply work in the last five years, in which much material has been centralized, and the custodians of the material have been co-ordinated. Attention is directed particularly to the standard stock book in effect over the system. It is similar to the standard recommended by the American Railway Association and is supplemented by a set of master stock books in the general office which comprises more than 300 volumes. Consistent with the typical procedure, inventories are taken at all reporting storehouses according to

a prescribed schedule which requires the inventorying of specified classes of material on prescribed days of each month and the forwarding of the regulation stock book coupons to the general office where the coupons are pasted in the

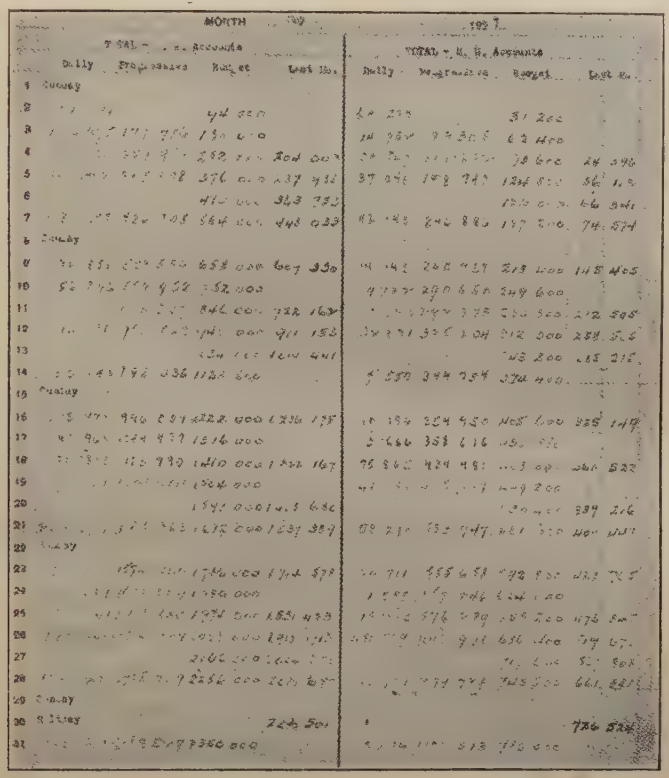


Fig. 4. — Daily progress record for total maintenance of equipment materials and total maintenance of way materials for typical month.

Similar records are kept for each class of material.

master stock books for use in checking orders against available and used materials, and in filling requirements as far as possible by transfers from points with surpluses, thus reducing purchases and reducing excess or slow moving stock. It is pointed out that this work is not only carried out independently of the budget but has been given a superior operation by the practice of determining the quantities directly from the stock books instead of waiting for requisitions and also by the use of a special form with the names of all sources of supplies printed on it so that the information necessary to a transfer or purchase order is quickly provided by a mark or two in the proper place. The fact that approximately 15 000 transfers of material are made a month is offered as further evidence of the reliance placed upon stock books in the disposition of supplies on this road.

Attention is also called to the fact that, consistent with modern practice, this

Company has its material classified and that each month classified material reports along the lines recommended by the American Railway Association are prepared for 19 different divisions showing the stock on hand, received and used for each class of material. These statements receive the attention of the proper storekeepers and also are available to eight material supervisors who are continuously checking the status of material on the ground.

Stock books not adequate.

There is no disagreement with those who want the stock book preserved. The difference arises only on the question of adequacy. The Pennsylvania System, it is pointed out, is a large road. It ranks first among the railroads of the country in total trackage, total assets, total freight and passenger traffic, and gross revenue.

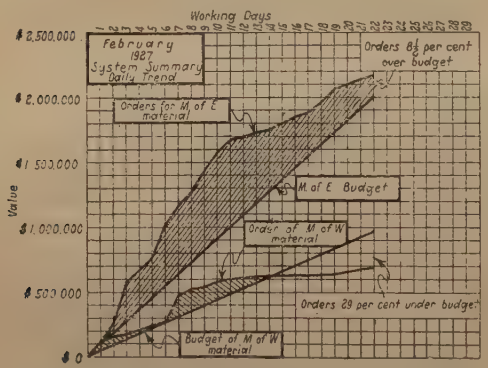


Fig. 5. — Chart showing operation of budget for total maintenance of equipment and also for maintenance of way materials during February 1927.

Note relation of order curve to budget line in each case.

The mileage of this road is 11 100 and the trackage 26 900. During 1926, requirements of material for operating and maintenance amounted to $161 068 000. This expenditure included $41 989 000 for fuel, $9 595 000 for rail and $11 million 365 000 for ties, but it also included $9 516 000 for frogs, switches and rail fastenings, $4 650 000 for wheels and tires, $1 562 000 for locomotive tubes, $4 709 000 for lumber and timber, $7 million 409 000 for electrical materials, $2 777 000 for lubricating oils and grease, etc., and $2 307 000 for air brake material.

The extent and complicity of its supply work is further indicated by the fact that these purchases were made from some 7 500 individuals, firms and corporations, embraced 75 000 separate sizes and varieties of stock and called for more than 250 000 requisitions and 500 000 sellers' invoices.

Material is received and held for use at 3 905 places comprising 34 main stores and 26 sub-stores from which material is delivered for working stocks to 676 minor shops, engine houses and inspection points for maintenance of equipment material as well as small working supplies for maintenance of way use of which 118 accommodate the master carpenters, 143 the supervisors of signals, 227 the supervisors of track and 2 681 the section houses, though they are under the control of the general storekeeper. The great bulk of the material is concentrated in the department's 34 main stores but it is pointed out that the materials at all points form the stock of unapplied material which must be kept in control.

The necessity of stock books in operations of this scope is that it follows the history of each item of material. The futility of a system of control that does not analyze each unit is granted in supporting the budget, for the knowledge that material of a certain value is carried is quite as often apt to be injurious as useful if the material turns out to be bolts when nails are required but it is argued that a knowledge of value is quite as essential to the best results. It is emphasized that a railroad, while responsible for service to the public, is nevertheless a business conducted for profit and that the measure and substance of profit is

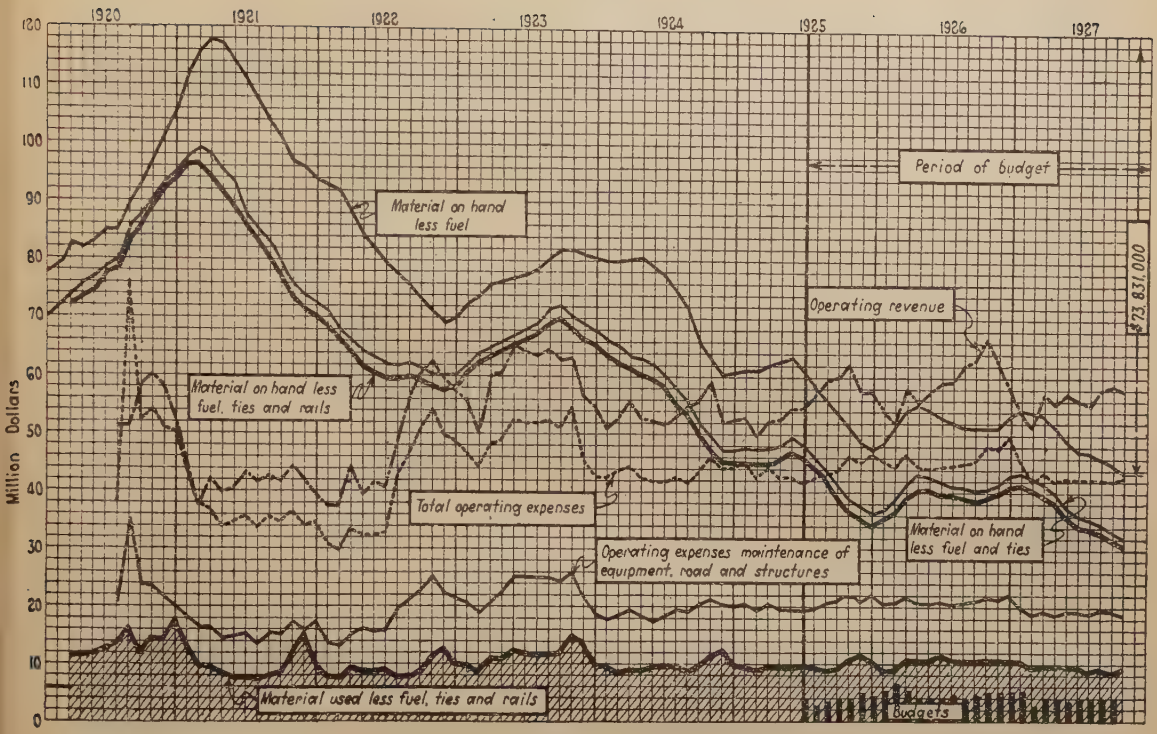


Fig. 6. — Comparative trends of operating revenues and expenses, and values of material on hand and used by months on the Pennsylvania Railroad from 1920 to the end of 1927.

Note huge reduction in material on hand.

money. The basis of the stock book is consumption, but constantly in the cycle of efficient control this consumption must be visualized in terms of money if a proper balance of operations is to be obtained. The insufficiency of the stock book alone to control is indicated, it is argued, by the universal demand of stores officers themselves for monthly statements disclosing the value of unapplied stock on hand and consumed. Such statements reflect past performance but are in a measure « water over the dam » and are of no direct assistance in guiding the tremendous operations of the immediate present. Indeed certain of such statements are not available when preparations for the current month must be made.

Thus the purchase budget is pictured as a needed link in the supply chain that an operation such as the Pennsylvania requires. In the same way and on the same principle that operating expenses are budgeted to keep operations in harmony with revenue the purchase budget is devised to keep the flow and status of material in harmony with operating expenses. The judgment concerning the future which even the storekeeper must use in operating his stock books is checked by judgment based on a knowledge of the actual expenses and a picture is given of each day's operation in relation to fixed objectives, which makes it much easier for the road to detect and adjust itself in a moment to those unexpected contingencies or conditions which, if not

Pennsylvania Railroad Company.

General Storekeeper's budget allowance for Commitments month of March 1927.
(000 omitted.)

ACCOUNT NUMBER.	Budget for March.			February Commitments.		
	Philadelphia.	Altoona.	Total.	Philadelphia.	Altoona.	Total.
1.	45	15	60	33	22	55
2.	135	23	158	89	4	93
3.	33	9	42	35	3	38
6.	39	15	54	7	7	14
7.	35	8	43	62	3	65
8.	42	39	81	66	49	115
9.	57	5	62	18	...	18
10.	17	11	28	3	3	6
11.	77	6	83	70	...	70
12.	18	23	41	3	11	14
13.	25	13	38	2	4	6
14.	44	15	59	30	50	80
16.	39	26	65	44	36	80
18.	28	17	45	7	6	13
19.	55	120	175	24	79	103
20.	62	13	75	59	1	60
21.	28	9	37	27	6	33
22.	258	22	280	53	10	63
23.	113	7	120	93	4	97
24.	7	106	113	6	82	88
26.	2	15	17	...	22	22
27.	20	194	214	21	217	238
28.	47	17	64	74	25	99
29.	128	102	230	94	28	122
30.	125	13	138	139	15	154
34.	37	12	49	21	7	28
35.	2	...	2	3	...	3
36.	36	2	38	33	1	34
38.	110	34	144	135	30	165
42.	78	30	108	89	35	124
44.	45	42	87	32	27	69
M E.	1 787	963	2 750	1 372	797	2 169
52.	250	...	250	106	...	106
53.	800	...	800	430	...	430
54*a*	5	...	5	2	...	2
55.	90	...	90	42	...	42
56.	50	...	50	38	...	38
57.	10	...	10	2	...	2
58	25	...	25	19	...	19
59*a*	5	...	5	1	...	1
59*b*	5	...	5	1	...	1
60.	30	...	30	10	...	10
61.	15	...	15	6	...	6
63	5	...	5	11	...	11
64.	35	...	35	14	...	14
M W	1 325	...	1 325	682	...	682
Total. . .	3 122	953	4 075	2 054	797	2 851
F & I	136	64	200	136	64	200
Total. . .	3 258	1 017	4 275	2 190	861	3 051

Copy of a typical purchase budget.

Gives allotments in thousands of dollars for each class of material and assigning the proportions for Philadelphia representing maintenance work and for Altoona representing manufacturing.

seen in their aggregate and in relation to total operations, may easily cause far reaching disturbance. Finally it is said of the Pennsylvania budget that after all it only represents the result of correlating and systematizing those efforts at controlling stock outside of the stock book which have always been practiced more or less in purchase operations, though often without the knowledge of stores officers. The needs of the user must be met, but these in turn, it is held, must be in harmony with value and the best method of injecting value into the system is by a plan which follows the value day by day, particularly when the purchasing policy is to buy only for current requirements as this road has always done.

While this road's purchase budget is both developed and administered at headquarters, and does not depend for its development or execution upon the subordinate stores officers, it is explained that with the small amount of office work done in even the large stores and their number and distribution, such a procedure would be impracticable at present even if it were desirable.

Over four million spent each month.

The budget plan was introduced in June 1925. Except for fuel, rail, cross-ties, and certain miscellaneous items, all materials and supplies, aggregating $4 000 000 to $4 500 000 per month, are embraced by it. It has been found that the rail, track ballast and cross-ties can be controlled more satisfactorily under a separate plan. Cross-ties are requisitioned on the purchasing agent about one year in advance of their need, to give the necessary time for seasoning and treatment. The quantities are based on the records of consumption during the preceding year, supplemented by the best information available regarding the prospective business conditions during the following year. Switch ties are handled in the same way. The rail program, on the other hand, is determined by the executives and distribution by months is arranged between the chief engineer, general purchasing agent and stores manager. After the rollings are arranged by the mills, the general storekeeper is given that information and arrangements are made by the store department for joint bars, bolts, nut locks, tie plates, etc., which are received, usually, within one week of the actual delivery of the rail. The values of ties and rail are included in the operating expense budget but are eliminated in arriving at the purchase budget.

Big reductions in stock.

Three charts (figs. 6, 5 and 2) are presented to illustrate the conditions under which the purchase budget operates and the results that are obtained. In the first chart (fig. 6) are shown the trends of the value of unapplied materials and the consumption of materials issues to closed accounts, compared with revenue, total operating expenses and total expenses for maintenance of equipment and maintenance of way and structures. The chart shows a notable uniformity in the consumption of material for the maintenance of equipment and maintenance of way in recent years and the uniformity of its relation to the operating expenses for these departments of work is also brought out. The extent to which total operating expenses exceed those for maintenance of way and equipment illustrates the reason why the purchase budget formula is based upon the maintenance of way and equipment expenses rather than upon total operating expenses.

A spectacle of the chart is the great reduction in the value of unapplied materials in the last six years, the value of material on hand including ties but excluding fuel at the end of May 1925, when the purchase budget was introduced, being approximately $55 000 000 less

than the peak value in 1921, while the value at the end of October, 1927, the last month on record, represents a further reduction of approximately $19 000 000 or a total of almost $74 000 000. Excluding ties and rails as well as fuel, the reduction from the peak in 1921 to last October was approximately $66 000 000. With the assistance of the budget, stores operations have been reduced to the basis of a 3.1 months' supply.

The second chart (fig. 5) gives an example of the operation of the budget and also illustrates the significance of converting the monthly allotments into a daily trend. The curve marked « maintenance of equipment budget » passes through those points on the chart which represent each day's allotment on the accumulative plan, while the line marked « orders for maintenance of equipment material » passes through the points representing the accumulated values of the orders placed throughout the month. Theoretically, orders should not cross the budget line. In this case the orders for equipment material exceeded the budget and by the 10th of the month were twice the prorated allotment but as a result of the attention immediately given, demands were reduced and the authorized allotment for the over-run was reduced to 8 1/2 %. In the case of maintenance of way materials, the orders exceeded the budget in the first part of the month but by the end of the month the total value of orders was considerably less than the authorized amount.

Variations from total budget small.

The third chart (fig. 2) gives the history of budgeting in the more important classes of material for each of the first 10 months of 1927. The three central charts refer to the budget for total maintenance of equipment material, total maintenance of way and structures material, less fuel, rail, ties and the total maintenance of equipment and maintenance of way and structures material, respectively. These are supplemented by 31 charts for as many groups of the materials which are included in the totals. The black column in each case gives the size of the authorized allotment in each month while the white column shows the volume of orders placed during the month under this allotment. The vertical distance between each square represents $25 000 in the case of the supplementary charts while the scale is $1 000 000 in the case of the central charts.

The miscellaneous charts show much variation, not only in the size of the allotments from month to month, but in the degree to which orders followed the budget. This is particularly the case with tie plates, spikes and other track material, which strikingly disclose the problem of the storekeepers in anticipating all the conditions that affect the use of these materials, even with the aid of stock books and other records of past performance. In contrast with this, the charts of the totals show marked harmony between the budget authorized each month and the value of the orders placed. In only two cases during the 10 months did the total value of orders exceed the total budget for maintenance of way and maintenance of equipment materials; and the average variation from the budget was 7 %.

Stress is particularly laid upon the harmony between total expenditures and total budget in discussing the efficiency of the budget plan, for, as explained, while the effort is made to keep the orders in line with allotments in all the various classes budgeted, it is only with the total budget that observance is insisted upon. It is permissible under the budget plan and it is regularly practiced to utilize the gain in one class of material during the month to meet the demand for additional money of another class as long as the total budget is not exceeded.

That much remains to be done in perfecting the construction and administra-

tion of the plan is recognized by the authorities, but at the present stage of operations the results are said to be increasingly satisfactory. Indeed, the difficulties encountered with the budget are considered evidence of the need for such a supplementary plan of controlling the vast expenditures of material which this road is required to make and control currently for its upkeep and operation.

[656 .281. (01]

Freight car derailments,

By T. H. SYMINGTON.

Figs. 1 to 5, pp. 518 to 522.

(*Railway Age.*)

When freight cars were all of small capacity, with low center of gravity and very flexible, they would not derail, when in fair condition, on track somewhat out of line or surface, or on average worn rail on curves.

Modern freight cars are of large capacity, high center of gravity and many are very rigid. Lower transportation costs necessitate the large capacity car, and the rigid car costs less to maintain than the flexible car. The savings thus effected are in some measure offset by the far greater construction and maintenance cost of the better track required for satisfactory operation of modern equipment.

The high capacity rigid freight car now in general use on American railroads will not be entirely satisfactory until it will never derail, when in fair condition, on track that is not perfect in line and surface, and with average worn rail on curves. Derailments caused by obstructions on track are not under consideration. It is impracticable always to maintain all main line track in such perfect condition that modern freight cars with the present standard truck construction will not sometimes derail.

Almost every important railroad in the United States has given separate consideration to freight car truck springs and side bearing clearance in connection with derailments and spring failures, and as these springs are also vital factors in connection with the life of rails, the time seems opportune to discuss the entire subject.

Many rigid freight car derailments on curves occur as a result of two simultaneous conditions: first, high wheel flange pressure against the rail caused by curving resistance, and second, an unloading of the truck spring on the same side of the truck, caused by warp in the track. Many high gravity freight car derailments on tangents also occur as the result of two simultaneous conditions: first, some wheel flange pressure against the rail, caused by trucks not squaring themselves after coming out of a curve, and second, by excessive car roll that may lift the wheel off the rail.

We cannot eliminate high wheel flange pressure on standard freight cars with present truck construction, because of center plate and side bearing frictional resistance. It is important, therefore, to minimize the unloading of the truck springs on curves and also to minimize car roll. Wheel flange pressure on cur-

ves is at its maximum when the car is loaded, because curving resistance increases with the car weight. The center of gravity of the loaded car is much higher than that of the light car and therefore the tendency to roll is greater for the loaded car.

Frequent minimum wheel load on 55 ton rigid cars on sharp curves 9 000 lb.

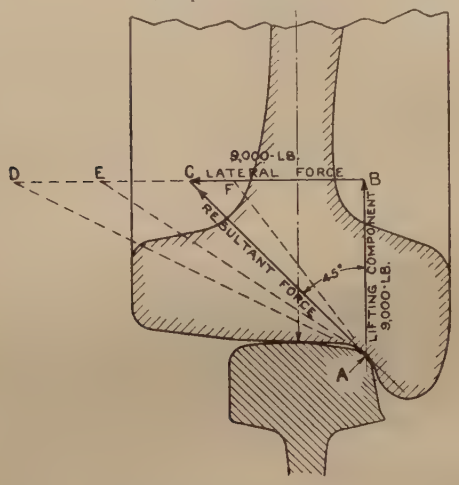


Fig. 1. — Resultant force line for a new wheel on an average worn rail.

Figure 1 shows a frequent relative condition of rail and wheel flange that may permit the wheel flange to climb the rail when there is high lateral pressure from curving resistance, and an unloading of the truck spring. The rail is average worn and the wheel is new. If there were no static transverse friction at point *A* the force diagram in full lines shows that the lifting component *AB* equals the lateral force *BC*, and the resulting force is *AC*. There *is* transverse friction at *A*, so that the resultant force *AC* may move to, say *AD*. When the wheel flange is rolling against the rail with high lateral pressure, the surface of the wheel flange has a tendency to gear itself to the surface of the rail head and lift the wheel. The resultant force *AD* is thereby moved to, say *AE*, or possibly to *AC*. With unusual wheel and worn rail contours it may move to *AF*. If the resultant force is at *AC* any more than 9 000 lb. pressure of the wheel flange against the rail will lift the wheel. If the resultant force is at *AE* a dangerous limit of flange pressure is 13 500 lb. and if the resultant force is at *AD* the dangerous limit of flange pressure is 18 000 lb.

When a very rigid car is running into a curve with maximum warp in the track, the whole car is tilted by the leading truck, and with minimum side bearing clearance, the rear end of the car is supported entirely on one side bearing only. The other end of the car has then its main support on the diagonally opposite side bearing. This condition is shown in figure 2 and it will be noted that the center plates are not in contact.

Under these circumstances the curving resistance of this rear truck is largely increased, because the lever arm of the entire curving resistance is 25 inches long. This results in high pressure of the opposite forward wheel flange of this rear truck against the rail. The static spring load on this wheel is then 6 785 lb. It is impossible to have a static spring load on one wheel of less than 6 785 lb. on a fully loaded 55-ton car when side bearings are spaced 50 inches apart. This wheel load on the rail with minimum spring pressure of 6 785 lb. added to its dead weight equals about 9 000 lb. and can only be reduced by a single car roll on a curve or by cumulative car roll on a tangent. This reduced weight is sometimes not sufficient to keep the wheel flange from climbing the rail, as the flange pressure against the rail is then at its maximum.

With 9 000 lb. wheel load on the rail (see fig. 1), it is evident that if the resultant force is at a less angle than 45° with these wheel and rail contours, the wheel will climb the rail with a lateral flange pressure of 9 000 lb. The importance of minimizing wheel flange press-

ure against the rail to prevent derailments is obvious.

Unloading of truck springs.

There are two kinds of unloading of truck springs. First, the unloading that occurs on very rigid body cars on curves, when the track is highly warped, and second, the unloading that may occur on high gravity cars because of excessive car roll.

When a car is entering a curve at fair speed and is tilted to the inside rail, a sudden change of line or surface in the track may cause the car body to roll to the inside of the curve and cause the truck springs to go solid. If the roll is sufficient, the resultant force line passes outside of the rail, and the entire car and truck may rotate on the rail and lift the opposite wheels with a resulting derailment, as shown in figure 3.

If the single roll on a curve or the cumulative roll on a tangent is not quite sufficient to lift the car wheel on the opposite side, a dynamic upward force on the wheel on this opposite side may cause the wheel to lift off the rail. This dynamic force would come from a sudden inequality in the surface of the track. The dynamic augment on the closed truck spring from excessive car roll depends upon the rolling velocity of the center of gravity of the car at the instant of spring closure. This dynamic augment is responsible for excessive bearing stresses in the rail head from car wheels.

Unloading of truck springs occurs on tangents as a result of car roll only. This roll results from track inequalities, such as low joints, etc. Synchronous car roll on tangent track may also cause the truck springs to go solid, as shown in figure 3, and break or take permanent set. It also occasionally results in derailments. Synchronous car roll is more pronounced with high gravity cars, particularly when they have large side bearing clearance.

Prevention of car roll.

Car roll can be greatly reduced by work absorption. The frictional resistance of elliptic springs will dampen cumulative roll but adequate elliptic springs have not been placed in standard freight car trucks. Car roll is always accompanied by lateral thrust and this force when lifting the car through lateral motion will greatly reduce car roll. Any lateral motion to be fully effective must produce adequate lift fully to absorb this lateral force without shock and with positive return to the central position. There are many different types of truck design that can be utilized.

The development of a satisfactory work absorption truck spring, or other bolster supporting means, will also break up cumulative car roll and act to prevent derailments which may result therefrom.

Side bearing clearance.

On old style flexible cars, large side bearing clearance was necessary to take care of the deflection under load of both body and truck bolsters and thereby avoid the curving resistance occasioned by excessive side bearing pressure. With modern cast steel truck bolsters and rigid body bolsters there is practically no deflection. With rigid bolsters, large side bearing clearance is needed solely to prevent the unloading of truck springs of rigid cars on curves. Figure 2 shows the position of the truck bolsters when one end of the car is carried entirely on one side bearing, which often occurs on rigid cars. Figure 4 shows how larger side bearing clearance brings the center plates into contact, thereby nearly doubling the load on the wheels on the danger side.

With rigid bolsters, side bearing clearance necessitates the truck bolster tilting on a corner of the center plate as shown. It will be noted that the lever arm from the fulcruming corner of the center plate to the center of the side bearing resist-

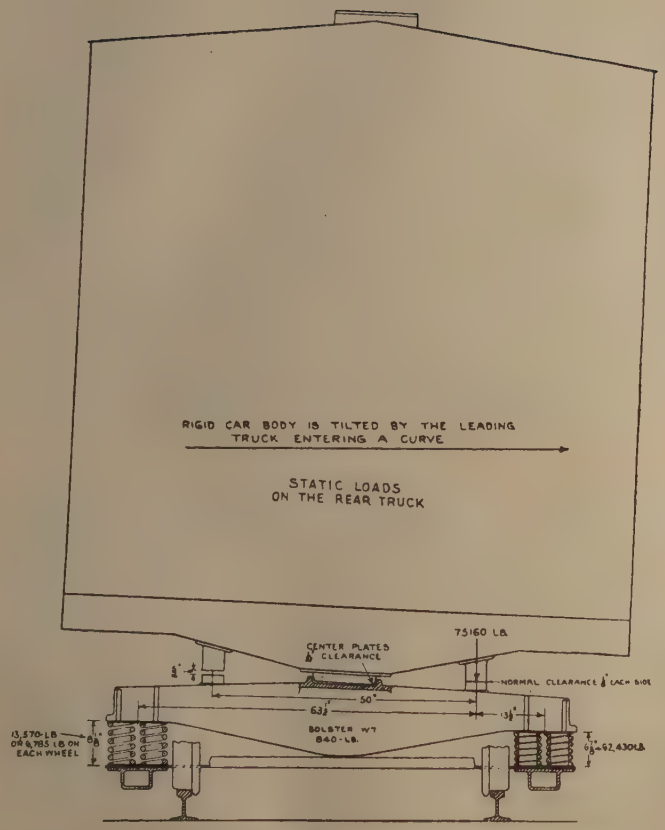


Fig. 2. — A rigid car body supported on diagonally opposite side bearings under the influence of maximum track warp on entering a curve. — Minimum side bearing clearance.

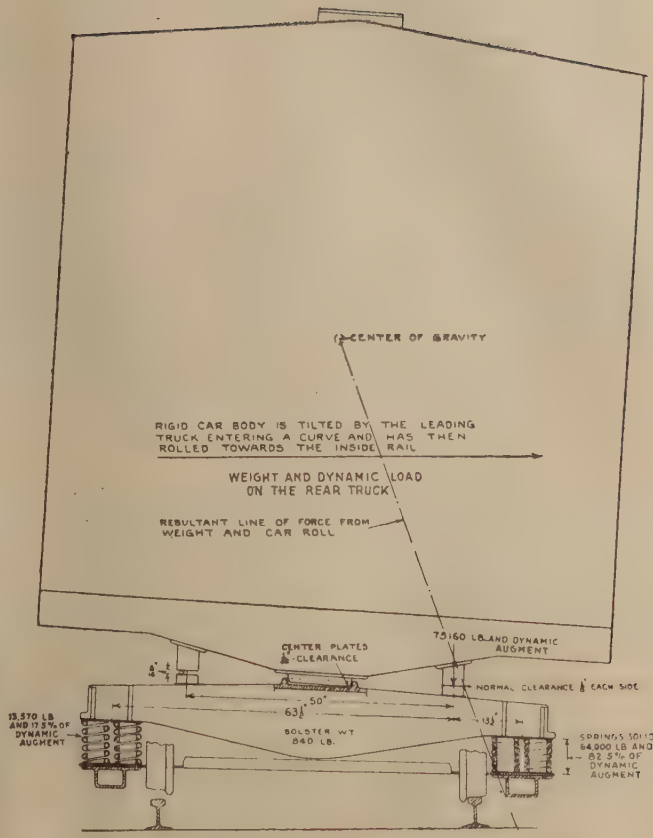

CENTER OF GRAVITY
RIGID CAR BODY IS TILTED BY THE LEADING TRUCK ENTERING A CURVE AND HAS THEN ROLLED TOWARDS THE INSIDE RAIL
WEIGHT AND DYNAMIC LOAD ON THE REAR TRUCK
RESULTANT LINE OF FORCE FROM WEIGHT AND CAR ROLL
CENTER PLATES
CLEARANCE
75160 LB. AND DYNAMIC AUGMENT
NORMAL CLEARANCE EACH SIDE
50"
63"
13"
BOLSTER WT 840 LB.
13,570 LB AND 17.5% OF DYNAMIC AUGMENT
SPRINGS SOLID 64,900 LB AND 82.5% OF DYNAMIC AUGMENT

Fig. 3. — Conditions which may result from rolling of the car body when the car is entering a curve.

ance is 19 inches long and the lever arm from the fulcrum to the center of the opposite spring nest is 44.5 inches long, from which it is evident that 3/16 inch side bearing clearance on each side produces the equivalent of an additional

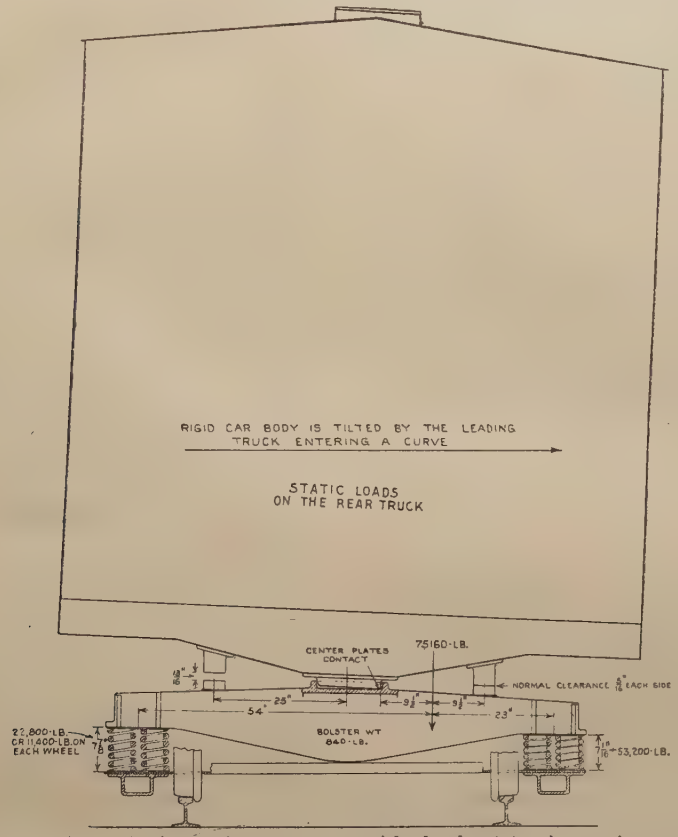


Fig. 4. — Static loads on the rear truck with the front truck entering a curve. Increased side bearing clearance.

7/16 inch travel in the truck spring. This downward movement on the danger side is always two and one-third times the side bearing clearance on one side when the bearings are spaced 50 inches apart. As large side bearing clearance invites car roll, many roads using large side bearing clearance also use lateral motion trucks to dampen any excessive roll.

In order to determine the minimum side bearing clearance for any type of rigid car, it can be placed when light on a very short radius curve with maximum warp in the track between truck centers and then determine the side bearing clearance that insures carrying part of the load on the corner of the center plate.

Truck bolsters.

As large side bearing clearance insures a rigid truck bolster tilting, this tilting puts 75 000 lb. on one corner of the cen-

ter plate on a 55-ton car. The excessive stress thereby localized in the body center plate sometimes results in breakage. Wherever large side bearing clearance is used, the truck bolster may be made like

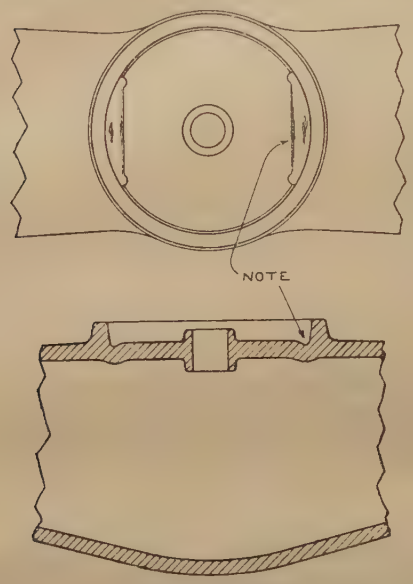


Fig. 5. — Suggested form of truck center plate to protect the body center plate when tilting.

figure 5 to permit the bolster to rock on a line instead of a point and thereby distribute the high concentrated stress in the body center plate. This rocking line should not be produced by clearance on the body center plate as the tilting is always on the axis of the truck bolster.

Curving resistance is reduced on new cars by machining both the body center plate and its bearing on the truck bolster, as without machining there may be an interlocking of the two rough surfaces, particularly under the high concentrated pressure that occurs when the bolster tilts. Under this latter condition the entire center plate resistance to curving has a lever arm nearly 6 inches long. When side bearing clearance is very accurately adjusted, this machining will insure the maintenance of the desired clearance.

Balled center plates.

Large side bearing clearance has been used with balled center plates. The objection to this construction is that there is no normalizing force to return the car body to horizontal position and the bolsters are apt to run in contact at one side bearing and with double the normal side bearing clearance at the other side. Under this condition a sudden shift will invite high dynamic stresses, because this stress resulting from 1/2 inch movement is four times the dynamic stress resulting from 1/4 inch movement.

Dynamic shocks destroy many roller side bearings. A damaged roller side bearing may cause greater curving resistance and wheel flange pressure than plain friction side bearings.

Truck springs.

Soft flat curve truck springs make a freight car ride easier, but easier riding is of secondary importance in comparison with the necessity of avoiding the dynamic shocks that result when the springs go solid with car roll caused by track inequalities, and also in comparison with the necessity for having the springs maintain their designed travel and capacity to insure their proper operation.

Car roll, causing A. R. A. (American Railway Association) standard truck springs to go solid and break, has resulted in a large output of these springs that are soft and, therefore, take a permanent set. It is a safe statement that one-half of the A. R. A. standard truck springs in operation today have taken a set through car roll after a year's service, and have thereby lost travel and capacity. The A. R. A. standard truck spring nest for 55-ton cars has a designed capacity of 64 000 lb. and a travel of 1 11/16 inches. A set of 1/4 inch reduces the capacity to

54 000 lb. and the travel to 1 7/16 inches. A large number of these A. R. A. springs in service today have less than 1 inch travel and proportionally reduced capacity. With the reduced capacity of the truck springs through set, cars are much more apt to roll the springs solid and increase the set. The result is progressive.

With spring travel reduced through set, rigid cars are more apt to derail on curves, because the springs are unloaded with less warp in the track. On many rigid cars that derail on curves the truck springs have less than the designed travel and capacity. This fact can be readily checked by measuring the height of the A. R. A. standard spring nest on any derailed car. Its free height should be 8 1/2 inches, its light car height should be 8 3/4 inches, and its fully loaded height should be 7 1/2 inches.

To meet the problem of reduced capacity, the number of standard spring coils can be increased and thereby increase the capacity of the spring group. Car roll may give these larger spring groups a permanent set and the progressive loss of capacity and travel in service is simply deferred.

Where truck springs with a rated capacity of 64 000 lb. for 55-ton cars and 80 000 lb. for 70-ton cars have been found inadequate, the actual capacity of the 55-ton car spring would often not exceed 48 000 lb. and the 70-ton car spring would often not exceed 60 000 lb. because they had both taken a permanent set which is the result of car roll on too soft springs. If the standard truck spring nests with their rated capacity go solid in service when excessive car roll is prevented, then only would it seem necessary to increase the capacity of the spring group by adding coils or by using stiffer coils.

If car roll is prevented, the A. R. A. standard spring nests properly made will, I believe, maintain their travel and sufficient capacity, and A. R. A. standard side frames and bolsters are thereby maintained. It would seem desirable to have truck springs break when overstrained instead of taking a set, because a broken coil can be seen and replaced. The spring that has taken a set is too often allowed to run, and may ultimately cause trouble.

Types of truck springs.

Freight car truck springs in general use can be divided into three groups, as follows :

TYPE.	Travel.	Full load 55-ton car.	Approximative capacity 55 ton car.	Approximative fibre stress at closure.
Standard A. R. A.	1 11/16 inches	38 000 lb.	64 000 lb.	80 000 lb.
Baltimore & Ohio	2 inches	38 000 lb.	88 000 lb.	80 000 lb.
Norfolk & Western	1 3/8 inches	38 000 lb.	98 000 lb.	80 000 lb.

These different spring coils are used in different groupings for 40, 50 and 70-ton cars in order to get the desired capacity.

A. R. A. standard coil. — This spring coil, properly made, would I believe, be generally satisfactory in the various standard groupings for different capacity cars, if car roll is prevented. Its fibre stress when closed is 80 000 lb. Its travel of 1 11/16 inches is always augmented by more or less side bearing clearance to prevent derailments of rigid cars on curves. This spring coil is probably used on 90 % of the cars in service today.

Baltimore & Ohio spring coil. — This spring coil has a travel of 2 inches and a fibre stress at closure of 80 000 lb. Its free height is 11 inches and therefore it cannot be used in A. R. A. standard trucks. With 2 inches travel, car roll should be dampened by some means.

Norfolk & Western spring coil. — This spring coil is of standard height and fits the standard truck. It has 1 3/8 inches travel and its fibre stress when closed is 80 000 lb. Four double coils for 55-ton cars have a capacity of 98 000 lb. and five double coils for 70-ton cars have a capacity of 123 000 lb. This spring, properly made, should have long life, if car roll is prevented, because of its low fibre stress under normal working load. It will break when it goes solid from car roll as readily as any other coil. The only disadvantage of this spring coil is its reduced travel. With its low fibre stress under normal load this spring should not take permanent set if car roll is prevented, and its sustained travel of 1 3/8 inches will after short service exceed the 1 11/16 inches travel of the standard spring coils that do take permanent set when car roll is not prevented. Its capacity of 123 000 lb. in five coils for 70-ton cars exceeds by 11 000 lb. the capacity of seven A. R. A. coils.

Flexible cars should not derail on curves even with short travel springs and small side bearing clearance, because the truck springs are never unloaded. If the flexible car is of high gravity, car roll must be minimized. Adequate roller side bearings are desirable only to reduce wheel flange and rail wear and to reduce train resistance. Well made springs of any travel and of sufficient capacity are satisfactory if car roll is prevented.

If short travel springs are used on rigid cars, larger side bearing clearance must be provided to prevent spring unloading and derailments on curves, and car roll must be prevented in order to maintain the designed spring travel and capacity. If long travel springs are used, car roll must be minimized to insure the permanence of the long travel and to avoid derailments when the springs roll solid.

Adequate roller side bearings are more desirable on rigid cars, because wheel flange pressure is said to be less with roller side bearings than with friction side bearings, and when the truck springs unload on a curve there is, therefore, somewhat less tendency for the wheel flange to climb the rail.

A good inspection rule for spring travel and side bearing clearance for rigid cars might be that the actual truck spring travel plus two and one-half times the side bearing clearance on one side should never be less than 1 7/8 inches. With standard A. R. A. springs and 1/8 inch side bearing clearance on each side this figure is 2 inches.

If high pressures between wheel flanges and rails are eliminated, a very large percentage of freight car derailments are eliminated, regardless of the type of truck spring used.

If freight cars are equipped with adequate lift lateral motion trucks, or other work absorption means, so that car roll is minimized, the spring problem is solved. Springs will then not go solid and break or take a set, that sometimes results in very rigid cars derailing on curves and high gravity cars derailing on tangents. Damage to rails from car wheels is also thereby minimized.

Recent tests of freight train curving resistance, made at the University of Illinois, and reported by Professor Edward C. Schmidt, in the *Railway Age* of 10 September 1927, are very illuminating. The general average curve resistance at various speeds for all trains tested was 0.51 lb. per ton per degree on a level one-degree curve and 0.54 lb. per ton per degree on a level three-degree curve. This means that the curving resistance on a three-degree level curve equalled 1.62 lb. per ton, or 32.8 % of the average

rolling resistance on straight track as recorded in these tests.

The study of this entire subject has become one of major importance since the advent of modern, high capacity, high gravity, rigid cars.

We do not know what the shock pressures on a rail are when the truck springs go solid through car roll.

We do not know how much work absorption is needed to prevent cars rolling their springs solid.

We do not know what the lateral pressure is between the wheel flanges and the rail when cars are curving with different types of trucks.

We do not know what the derailing flange pressure from curving resistance is with different types of cars and trucks, and on differently worn rail.

We do not know the effect on wheel flange pressure of varying side bearing clearance.

We do not know the effect on wheel flange pressure of roller side bearings.

We do not know the effect on wheel flange pressure of lubricated center plates and plain side bearings.

We do not know what the lateral shock stresses are on rail with and without the use of lateral motion trucks.

We do not know what the lateral shock stresses are from guard rails, that sometimes break wheel flanges, with and without lateral motion trucks.

We do not know the relative curving resistance of rigid and flexible trucks.

We do not know whether we need or do not need self-squaring trucks.

We do not know how much train resistance can be reduced by minimizing curving resistance and resulting flange friction on curves and tangents.

We do not know how much we can increase the life of wheel flanges and rail by minimizing flange friction.

We have almost as many theories on all these vital subjects as there are major railroad systems in this country.

This particular field for research is certainly a large and attractive one.

[385 .115 (.44)]

Annual statement for 1926 of the working of the French State Railways

abstracted from the Administrative Accounts published for the said year.

(Taken from an article in the *Revue générale des Chemins de fer.*)

The results are summarised in the following seven tables :

Table I : *Capital expenditure.* — Table II : *General operating results.* — Table III : *Rolling stock : Stock and capacity.* — Table IV : *Rolling stock : Mileage of locomotives and other rolling stock.* — Table V : *Rolling stock : Mileage and composition of trains* — Table VI : *Profits accruing to the State from the operation of the system.* — Table VII : *General financial results.*

I. — Capital expenditure.

The returns analysed only indicate capital expenditure incurred during the financial year. We think it advisable to give below the total capital expenditure for the system operated, year by year, back to 1913, as taken from the statistical returns of the Ministry of Public Works.

LINES OPERATED.	Works.	Rolling stock.	Total.
Expenditure to 31 December 1912 :	Francs.	Francs.	Francs.
Contributed by the State.	1 102 021 588 (1)	...	1 102 021 588 (1)
— local authorities	103 062 754	...	103 062 754
— the system	2 253 093 185	644 081 008	2 897 174 193
Total to 31 December 1912. . .	3 458 177 527	644 081 008	4 102 258 535
Expenditure subsequent to 31 December 1912 :			
In 1913 (2)	114 793 654	42 127 622	156 921 276
— 1914	59 972 070	20 228 238	80 200 308
— 1915	34 418 520	3 821 053	38 239 573
— 1916	39 132 857	101 850 592	140 983 449
— 1917	25 662 242	91 277 915	116 940 157
— 1918	39 539 499	65 800 164	105 339 663
— 1919	54 509 294	22 639 387	77 148 681
— 1920	101 799 175	95 751 378	197 550 553
— 1921	149 004 333	332 255 669	481 260 002
— 1922	150 927 317	418 712 679	569 639 996
1923	136 232 946	112 392 825	248 625 771
— 1924	155 042 815	101 011 077	256 053 892
— 1925	157 568 514	82 752 960	240 321 474
— 1926	142 834 618	114 616 318	257 450 936
Total to 31 December 1926. . .	4 819 615 381	2 249 318 885	7 068 934 266

(1) Including 99 918 600 francs expended by the Orleans Company on the lines ceded to the State in 1883.

(2) The figures for the period 1913-1914 are those comparable with the expenditure in 1913 in the statistical returns of the Ministry of Public Works.

II. — General operating results

	Total.	Per kilometre (per mile) operated.	Per train kilometre (per train-mile)
1. Receipts.			
a) Lines directly operated by the State Railways :	Francs.	Francs.	Francs.
Express. . . . Passengers	503 200 460	58 213 (93 683)	7.3776 (11.8729)
Express. . . . Luggage, dogs, parcels, cattle	319 704 233	36 985 (59 521)	4.6873 (7.5433)
Ordinary traffic	1 078 189 741	124 732 (200 733)	15.8077 (25 4396)
Miscellaneous and other than traffic receipts	51 905 844	36 004 (9 662)	0.7610 (1.2247)
Receipts from withdrawals from the operating reserves	1 127 866	130 (209)	0.0165 (0.0265)
Total.	1 954 128 147	226 067 (363 807)	28.6501 (46.1070)
b) Lines operated by the Light Railways Company :			
Brittany System. Traffic receipts	11 361 641	27 051 (43 534)	9.7410 (15.6763)
Brittany System. Receipts other than traffic	129 033	307 (494)	0.1106 (0.1796)
Gross total.	1 965 618 821	216 859 (348 994)	28.3341 (45.5985)
2. Expenditure.			
a) Lines worked by the State Railways :			
Headquarters	9 725 058	1 125 (1 810)	0.1426 (0.2295)
General charges. Pensions, superannuation and savings	80 232 293	9 281 (14 936)	1.1763 (1.8930)
General charges. Compensation, grants and various payments to the staff	1 331 208	154 (248)	0.0195 (0.0314)
General charges. Medical service	2 940 908	340 (547)	0.0431 (0.0694)
General charges. Taxes and costs of inspection	12 202 986	1 411 (2 271)	0.1789 (0.2879)
General charges. Contribution to assurance and reserve funds	1 843 800	213 (343)	0.0270 (0.0435)
General charges. Accidents	5 883 946	680 (1 094)	0.0862 (0.1387)
General charges. Miscellaneous	7 291 169	840 (1 352)	0.1065 (0.1714)
Operating	552 764 665	63 947 (102 911)	8.1043 (13.0424)
Rolling stock and locomotive running. Ordinary expenditure	743 251 931	85 984 (188 375)	10.8971 (17.5369)
Rolling stock and locomotive running. Renewals	3 056 171	353 (568)	0.0448 (0.0721)
Permanentway and buildings. Ordinary maintenance	201 699 669	23 334 (37 552)	2.9572 (4.7590)
Permanentway and buildings. Heavy repairs	70 463 963	8 151 (13 118)	1.0331 (1.6626
Unprovided and exceptional expenditure on renewals or heavy repairs as considered under article 47 of the financial law of the 13 July 1911	1 127 866	130 (209)	0.0165 (0.0265)
Miscellaneous expenses	3 726 734	431 (694)	0.0546 (0.0879)
Expenditure on previous financial years	434 282	50 (80)	0.0064 (0.0103)
Total.	1 697 946 656	196 430 (316 118)	24.8941 (40.0624
b) Lines operated by the Light Railways Company :			
Brittany system	12 939 099	30 807 (49 578)	11.0934 (16.8428)
Gross total.	1 710 885 756	188 756 (303 767)	24.6622 (39.6892)

III. — Number and capacity of rolling stock.

(Lines directly operated by the State Railways.)

CLASS OF STOCK.	Number and capacity.				Difference as compared with 1925.	
	At the 31 December 1925.		At the 31 December 1926.			
	Number.	Power in French steam horse power (in British H. P.)	Number.	Power in French steam horse power (in British H. P.)	Number.	Power in French steam horse power (in British H. P.)
Locomotives	4 111	4 257 889 (4 199 713)	4 090	4 248 224 (4 190 181)	— 21	— 9 665 (9 532)
Rail motors	149	94 286 (92 998)	231	149 410 (147 368)	+ 8	+ 55 124 (54 370)
Express vehicles.	Number.	Capacity.	Number.	Capacity.	Number.	Capacity.
		Seats.		Seats.		Seats.
Passenger vehicles	(1) 7 641	383 769	(1) 7 635	387 853	— 6	+ 4 084
Passenger rail motors	113	6 320	192	10 744	+ 79	+ 4 424
		Metric tons (English tons).		Metric tons (English tons).		Metric tons (English tons).
Brakes	2 399	14 000 (13 779)	2 410	16 157 (15 902)	+ 11	+ 2 157 (2 123)
Various wagons	3 578	31 267 (30 773)	3 697	33 540 (33 010)	+ 119	+ 2 273 (2 237)
		Horses.		Horses.		Horses.
Horse boxes	326	1 306	315	1 260	— 11	— 46
Ordinary vehicles.		Metric tons (English tons).		Metric tons (English tons).		Metric tons (English tons).
Goods wagons	79 205	1 321 009 (1 300 145)	78 298	1 310 022 (1 289 331)	- 907	— 10 987 (10 814)
Service wagons	1 919	18 979 (18 679)	1 933	19 107 (18 805)	+ 14	+ 128 (128)
Special wagons	4	90 (88.6)	4	90 (88.6)	"	"

(1) 3 buffet cars not included.

IV. — Mileage of engines and other rolling stock and average loading.

	1925, kilometres (miles).	1926, kilometres (miles).	Differences as compared with 1925. Total, kilometres (miles).	Per cent.
I. — Total engine mileage :				
of the State System	84 427 333 (52 461 671)	84 947 358 (52 784 805)[a]	+ 520 025 (323 274)	+ 0.62
of the other systems	187 856 (116 730)	219 201 (136 207)	+ 31 345 (19 477)	+ 16.69
Total.	84 615 189 (52 578 401)	85 166 559 (52 921 012)	+ 551 370 (342 611)	+ 0.65
II. — Total mileage of other rolling stock (of the State System and of the other Systems) :				
Passenger vehicles	328 711 592 (204 255 604)	320 495 738 (199 150 417)[b]	— 8 215 854 (5 105 197)	— 2.50
Brake and other express vehicles	151 430 846 (94 096 465)	158 338 769 (98 388 937)	+ 6 907 923 (4 292 482)	+ 4.56
Ordinary goods wagons	851 224 838 (528 936 160)	923 285 065 (573 713 108)	+ 72 060 227 (44 776 948)	+ 8.47
Total.	1 331 367 276 (827 288 229)	1 402 119 572 (871 252 462)	+ 70 752 296 (43 964 233)	+ 5.31
III. — Mean annual mileage (*c*) :				
of a locomotive	33 562 (20 855)	33 334 (20 713)	— 228 (142)	— 0.68
of a passenger vehicle	44 845 (27 865)	44 611 (27 720)	— 234 (145)	— 0.52
of a goods wagon	12 788 (7 946)	14 022 (8 713)	+ 1 234 (767)	+ 9.55
IV. — Average load (*d*) :				
of a carriage : number of passengers	16	16.4	+ 0.4	+ 2.5
of a wagon : express goods, metric (English) tons.	2.3 (2.26)	2.2 (2.16)	— 0.1	— 4.3
of a wagon : slow goods, metric (English) tons	8 (7.87)	8.2 (8.07)	+ 0.2	+ 2.5
of a goods train : express goods, metric (English) tons.	55.3 (54.4)	52 (51.2)	— 3.3 (3.2)	— 6
of a goods train : slow goods, metric (English) tons	177.7 (174.9)	180.3 (177.4)	+ 2.6 (2.5)	+ 1.5
of a passenger train, number	124.7	128.5	+ 3.8	+ 3

(*a*) Including 12 054 628 km. (7 490 533 miles) shunting in yards; excluding 5 325 376 km. (3 309 095 miles) run by other than steam locomotives.
(*b*) Including 8 170 070 km. (5 076 738 miles) run by automotor vehicles.
(*c*) Excluding locomotives other than steam.
(*d*) These loads only include commercial traffics.

V. — Mileage and average composition of the trains.

(Excluding the Brittany System.)

DESCRIPTION OF THE TRAINS.	1925	1926	Differences as compared with 1925.	
			Totals.	Per cent.
Ordinary trains.				
Total mileage of trains, kilometres (miles) .	67 221 473 (41 770 241)	68 206 438 (42 382 281)	+ 984 965 (+ 612 040)	+ 1.47
Number of trains running daily on an average, a whole trip	21.31	21.62	+ 0.31	+ 1.46
Average number of vehicles of a train (including foreign vehicles) . . . . . Carriages . .	4.89	4.70	— 0.19	— 3.89
Wagons . .	14.92	13.54	— 1.38	— 9.25
Total. - .	19.81	18.24	— 1.57	— 7.93
Service trains.				
Total mileage of trains, kilometres (miles) .	338 332 (210 233)	396 670 (246 483)	+ 58 338 (+ 36 250)	+ 17.24
Number of service trains running daily on an average, a whole trip	0.11	0.13	+ 0.02	+ 18.19
Average number of vehicles in a train. . . . . Carriages . .	...	...	...	...
Wagons . .	19.89	19.89	...	...
Total. . .	19.89	19.89	...	...
Ordinary and service trains together.				
Total mileage of trains, kilometres (miles).	67 559 805 (41 980 485)	68 603 108 (42 628 775)	+ 1 043 303 (+ 648 290)	+ 1.54
Number of trains (ordinary and service trains together) running daily on an average, a whole trip	21.41	21.74	+ 0.33	+ 1.55
Average number of vehicles in a train. . . . . Carriages . .	4.86	4.67	— 0.19	— 3.91
Wagons . .	14.94	13.57	— 1.37	— 9.17
Total . . .	19.80	18.24	— 1.56	— 7.88

VI — The profits accruing to the State from the working of its system.

KIND OF PRODUCT.	1925 financial year.	1926 financial year.
Length of system (average length operated)	9 058 km. (5 628 miles)	9 064 km. (5 634 miles)
I. — Taxes on Transport.	Francs.	Francs.
1. Taxes on passenger and fast and slow goods	105 871 540	186 558 591
2. Stamps on receipt and carriage notes	10 138 744	13 770 961
Total under heading No. I.	116 010 284	200 329 552
II. — Taxes on deeds, titles, etc.		
1. Agreed payment for stamp duty on stocks and shares	3 628 778	5 747 929
2. Duty on transfer of bonds (inscribed or bearer)	6 451 780	8 434 140
3. Tax on income from stocks and shares, deposit accounts, etc., tax on the premiums of repayment on dated securities, etc.; tax on bills and on deeds deposited as security	15 647 644	30 033 474
4. Fiscal taxes	1 050 078	1 251 377
Total under heading No. II.	26 778 280	45 466 920
III. — Other duties on taxable matters created by the Railway industry.		
1. Tax on property built upon	2 622 845	3 995 364
2. Corporation tax	1 533 122	3 155 283
3. Custom dues on coal and coke used by the Companies and on various other materials used in service (steel, iron castings, etc.)	3 585 878	4 986 147
4. Various taxes (duties on licences, stamps, automobiles, etc.)	785 458	871 017
Total under heading No. III.	8 527 303	13 007 811
IV. — Savings resulting from the clauses of the contract.		
1. Post Office	44 952 076	68 817 791
2. Carrying soldiers and sailors	15 139 905	17 582 846
3. Free travelling of the employees in the Indirect Taxes Service and in the Customs	4 455 988	8 727 983
Total under heading No. IV.	64 547 969	95 128 620
V. — Savings on the commercial rates, resulting from friendly agreements with the State.		
War transport	452 762	436 856
Gross total of taxes and savings — General totals	216 316 598	354 369 759
Gross total of taxes and savings — Per kilometre	23 881	39 096
Gross total of taxes and savings — (Per mile)	(38 432)	(62 918)

VII. — General financial results.

Ignoring book receipts and expenditures, the statement of the receipts and ordinary expenditure for the whole system, in 1926, is summarised in the following table, which also gives a comparison with the 1925 results :

	Financial year 1925.	Financial year 1926.	Differences compared with 1925.
Operating results :	Francs.	Francs.	Francs.
Receipts	1 485 729 672	1 965 618 821	+ 479 889 149
Expenditure	1 452 363 608	1 710 885 756	+ 258 522 148
Net balance (A)	33 366 064	254 733 065	+ 221 367 000
Operating ratio	97.75 (1)	87.04 (1)	— 10.71
Capital charges :			
Expenditure	323 283 336	374 293 761	+ 51 010 425
Receipts	40 196 041	69 443 476	+ 29 247 434
Net charges (B)	283 087 295	304 850 285	+ 21 762 990
Application of article 14 of the 28 June 1921 Agreement.			
Annual premium allocated to the system and to its staff in accordance with article 14 of the Agreement of the 28 June 1921 (C)	18 440 812	24 786 014	+ 6 345 202
Charges for the first year on the shares issued to cover the loss of earnings (D)	1 308 866	...	— 1 308 866
Loss of earnings (B + C + D — A)			
Loss of earnings on the lines partially operated, covered by the extraordinary expenditure account (2d section of the attached budget)	694 157	...	— 694 157
Loss of earnings covered by the Common Fund formed in accordance with article 13 of the Agreement of the 28 June 1921	268 776 751	74 903 234	— 193 873 517
Total loss of earnings	269 470 908	74 903 234	— 194 567 674

(1) By not taking into account the operating results properly speaking of the Brittany System, the operating coefficient of the State System in 1926 came to 86.89 %. In the same conditions in 1925 it would have been 97.58 %.

The balance between the operating receipts and expenditure, properly speaking, shews for 1926 a net plus balance considerably greater than that of the preceding year. The operating coefficient fell from 97.75 % to 87.04 %, or 10.71 %.

These results are due to increases in the rates made in 1926, increase in traffic and the drastic reduction in the operating costs, in spite of increased costs, due to economic causes, of materials and general expenses.

From one year to another the operating costs have increased considerably, on the one hand, owing to the Main Systems having had to pay the staff as from the 1 May and the 16 August 1926 temporary bonuses for the increased cost of living, taking into account the steadily increasing cost of living and, on the other hand, because the cost of temporary labour and the prices of all materials — especially fuel and permanent way material — have followed the general rise which has hit all the national industries.

The Report notes that the adverse balance of 74 903 234 francs would have been converted into an excess of 63 millions in round figures, had not the results of working the Paris suburban lines shewn a deficit of 138 millions (as against 143 in 1925).

On this point, the Report notes that the poor financial results obtained on the suburban lines is due more particularly to the large number of passengers profiting by season tickets at reduced fares. If the inner suburban area alone is considered, it will be found that the number of passengers carried under these rates was, in 1926, 87 912 878 which is equal to 71 % of the number of journeys made (124 445 775) in the inner suburban area, whilst the corresponding receipts shew 27 314 000 francs as compared with 71 942 700 francs, or only 38 %.

MISCELLANEOUS INFORMATION

[628 .245 (.73)]

1. — A dual side-pivot drop-door air dump car.

Fig. 1, p. 534.

(*Railway Age.*)

The Western Wheeled Scraper Company, Aurora, Ill., has developed and placed on the market a new low loading drop-door dump car of the side-hinge type, which is designated as the Western dual-pivot drop-door dump car and which has been designed to meet the special problems encountered in open pit mining or similar operations as well as in maintenance of way work.

The car is provided with side pivots or trunnions spaced at sufficient distances to eliminate the necessity of locking mechanism. The car body can be dumped to either side to an angle of 50° from the horizontal and as the car is tilted the doors, which form the sides of the car body, turn downward to form an apron to prevent the material falling too close to the track.

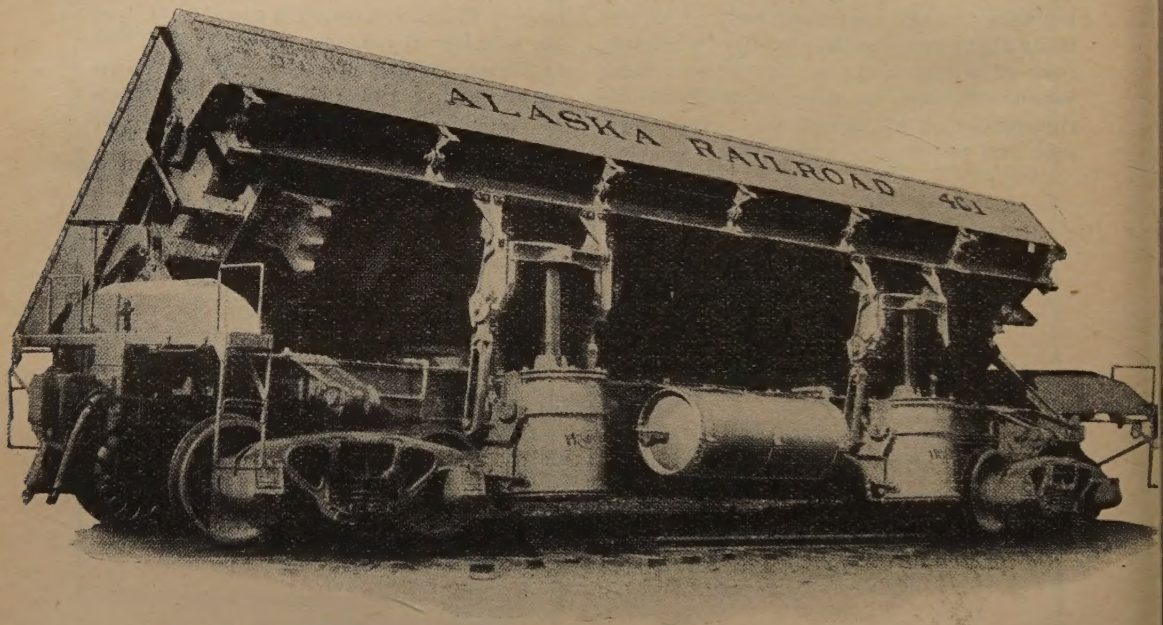


Fig. 1. — Western dual side pivot drop door dump car built for the Alaska Railroad.

When the car is in the dumped position the edge of the door is 4 ft. 8 in. from the rail. The insides of the doors and the ends of the cars are sloped to facilitate the discharge of the material.

Dumping is accomplished by two single-stroke cylinders on each side of the car, which

exert full pressure on the car body until it has reached an angle of 34° from the horizontal, when a link arrangement operates automatically to push the car body to the full dumping angle of 50°. The cars are provided with enamellined air storage reservoirs of sufficient capacity to dump the cars without relying on additional air from the locomotive and the piping arrangement is such that the cars can be dumped to either side, singly or in multiple.

When the car is being dumped the body rotates around six pivots until it has reached an inclination of approximately 40° from the horizontal. At this point the load is transferred to two outer pivots at the bolsters, causing the car body to right itself as soon as the air is released from the dumping cylinders. The inner pivots are set nearer the center of the car than is usual with this type of construction and are placed low, thus causing the center of gravity to follow a flattened curve when the car is tilted and thereby reducing the necessary consumption of air. It is said that the center of gravity of a uniformly distributed load of 100 000 lb. is raised only 6 1/2 inches during the dumping operation, reaching its highest point when the car body has been tilted 27°. Tests have shown that capacity loads were dumped with an effective pressure of from 45 to 52 lb. in the air cylinders and that the pressure decreases to less than 20 lb. during the latter part of the travel. The dumping is accomplished gradually but continuously and in these tests the load was completely discharged in from four to five seconds. The construction of the body is strong and rigid. The draft sill is made up of two 65-lb. I-beams with 1/2-inch cover plates on both the top and bottom, and 1/2-inch 30-lb. channels are used for the side sills. The cross sills are 8-inch I-beams closely spaced and fastened securely to the side sills, and rest directly on the draft sill when the car body is in its normal position.

The doors are formed of double plates, connected with ship channels at the top and bottom, with vertical diaphragms at all hinge points. When the doors are turning downward a constant clearance is maintained between the curved floor plate and the bottom of the door so that material will not lodge in this joint and prevent the righting of the car body.

The operation of the doors is controlled automatically by a system of levers located at each end of the car. The levers are enclosed to prevent fouling by material dropping from shovel dippers or loading buckets and the mechanism is designed to prevent injury in the event that the down-turning door strikes any dumped material along the track. The doors have ample strength to plow through dumped material without being damaged.

A number of these cars, of 25-cubic yard capacity, have been placed in operation at the Oxwell mine on the Mesaba iron range and more have been ordered. Similar cars of 30-cubic yard capacity, have been installed on the Alaska Railroad.